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A C O M P L E A T
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O F

General Geography:

E X P L A I N I N G

The Nature and Properties of the E A R T H;
V I Z.

It's Figure, Magnitude, Motions, Situation, Contents,
and Division into Land and Water, Mountains, Woods,
Desarts, Lakes, Rivers, &c.

With particular Accounts of the different Appearances
of the Heavens in different Countries; the Seasons of
the Year over all the Globe; the Tides of the Sea; Bays,
Capes, Islands, Rocks, Sand-Banks, and Shelves.

The State of the Atmosphere; the Nature of Exhala-
tions; Winds, Storms, Tornados, &c.

The Origin of Springs, Mineral-Waters, Burning Moun-
tains, Mines, &c.

The Uses and Making of Maps, Globes, and Sea-Charts.

The Foundations of *Dialling*; the Art of *Measuring*
Heights and Distances; the Art of Ship-Building, *Navigation*,
and the Ways of *Finding the LONGITUDE AT SEA.*

Originally written in *L A T I N*

By *B E R N H A R D V A R E N I U S*, M. D.

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By Sir *I S A A C N E W T O N* and Dr *J U R I N*;

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Mathematics, *Geography*, *Astronomy*, and *Navigation*.

By Mr *D U G D A L E*.

The whole Revised and Corrected by *P E T E R S H A W*, M. D.

The Second Edition, with large Additions.

V O L. II.

L O N D O N: Printed for *STEPHEN AUSTEN*, at
the *Angel and Bible*, in *St Paul's Church-Yard*. 1734.



BIBLIOTHECA

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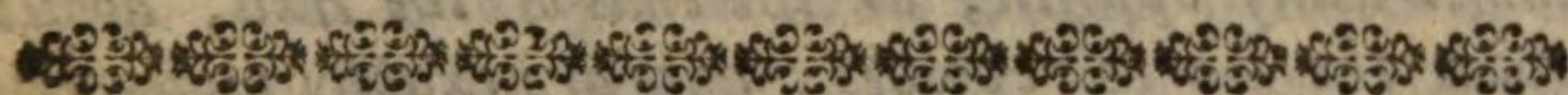
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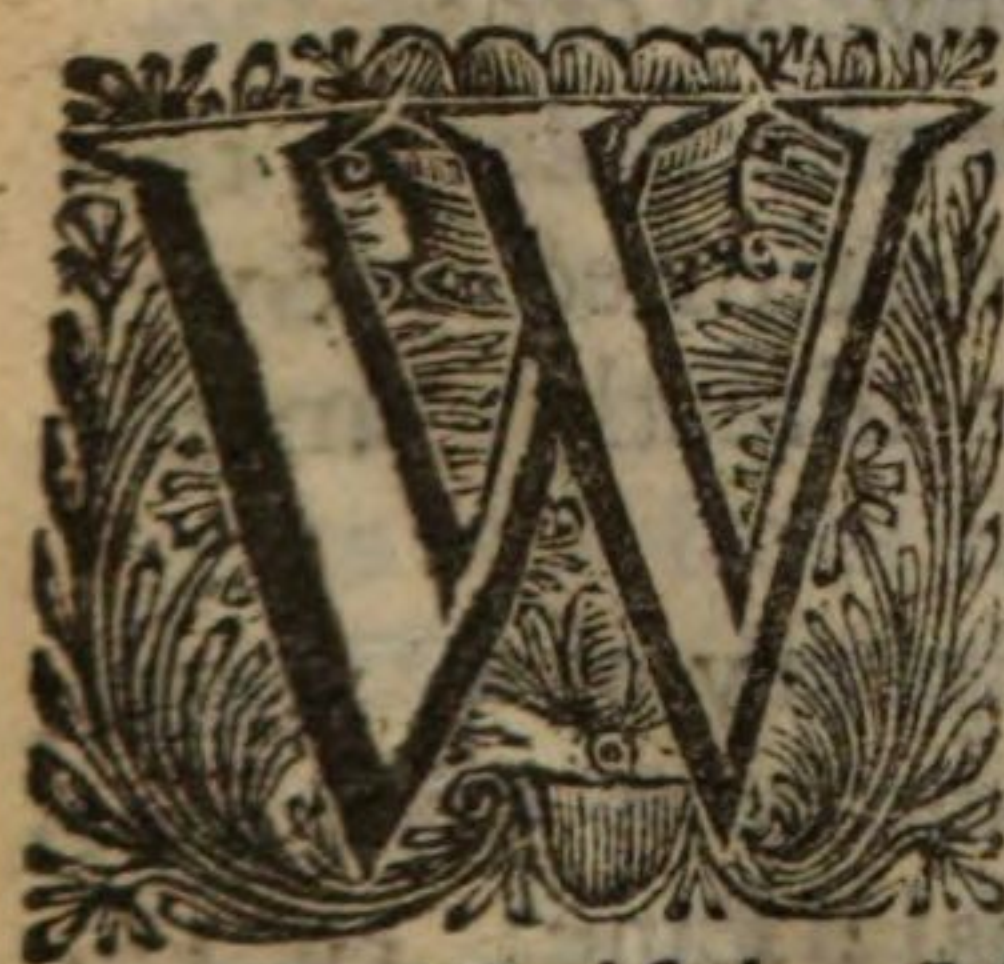
BOOK II.

*Of the Properties of Places on the Earth,
that arise from the apparent Motion of
the Stars.*



CHAP. XXII.

PRELIMINARIES.



WE have thitherto treated of *Geography, absolutely considered*; we come now to the second Part of this Doctrine, in which we shall consider the Properties of the Earth that depend on the apparent Motion of the Sun and Stars, and would not exist if that Motion did not appear: the Explanation of which will more properly belong to *Geography*,

graphy, if we suppose the Earth to move, as in *Chap. vi.* And for understanding hereof we must premise the following Definitions and Hypotheses.

DEFINITIONS.

1. *THE Artificial Terrestrial Globe* is a Globe made by Art, on whose Superficies the Parts of Earth are represented, in their proper Places, in the same Proportion which the Globe's Superficies hath to that of the Earth.

A *Map*, or *Geographical Table*, is a plain Figure, in which is represented the Situation of the Parts of the Earth's Surface ; and is *universal* or *particular* : the one shows the whole Superficies of the Earth ; the other a Part only. Some of them are made by strait, others by curve Lines ; both representing the Peripheries of Circles on the Earth. The Composition both of Globes and Maps we shall show at the end of this Book ; for it cannot be yet understood.

2. *THE Poles of the Earth* are two fixed Points diametrically opposite, at the ends of the Axis, about which the Earth revolves ; and are exactly under the two Points in the Heavens about which the Stars seem to revolve. The Pole that is under the Bear is the North, or Arctic, Pole ; the other the South, or Antarctic, Pole : which is better understood by seeing them on the Globe than by Words.

3. *THE Zenith and Nadir* are the Poles of the Horizon the former being the Point directly over our Heads, and the latter that directly under our Feet.

4. *THE Equator* is the Periphery of a great Circle on the Earth, equally distant from the two Poles, and is called the Equinoctial ; Line, or the Line, by Sailors in the way of Eminence ; and to it are all the Circles (described by the diurnal Motion

tion of the Stars) parallel; and therefore the Equator is that on which their diurnal Motion is measured.

5. THE *Circles* called *Parallels to the Equator*, are the lesser *Peripheries* parallel to it. On the Artificial Globe the Equator is more conspicuous than the *Parallels* or *Circles of Latitude*, and is divided into three hundred and sixty Degrees.

THESE may be also shown on the *Universal Geographical Maps*, whose curve Lines meet in the Poles. Those Maps that have only strait Lines have not the Poles, but the Meridians are supposed to terminate in them. The Equator in both is a strait Line cutting the Meridians at right Angles, tho' in some particular Maps, of *Asia* and *Europe*, 'tis curve; and also the *Parallels* are curve in curvilinear Maps, and strait Lines in others.

6. THE *Ecliptic* is also a great Circle in the Heavens, which the Sun describes by it's annual Motion: and tho' 'tis not proper to the Earth; yet 'tis drawn on the terrestrial Globe, and is seen on Maps, because of it's great use.

7. THE *Tropics* are two Circles parallel to the Equator, as far from it as the Sun goes towards the Poles; which is twenty three Degrees twenty nine Minutes, being the Angle the *Ecliptic* makes with the Equator; the one is called the *Tropic of Cancer*, on the North Side of the Equator; the other of *Capricorn*, on the South Side. They are marked on the Globe and Maps by a double Line, with their Names. And the *Polar Circles* are two *Parallels*, as far from the Pole as the *Tropics* are from the Equator, called *Arctic* and *Antarctic*. The Circles hitherto explained do not depend on certain Places as the following do.

8. THE *Meridian* of a Place on the Earth is the Line that passes from the North, over the Place to the South; above which when the Sun

comes 'tis Mid-day there, or the middle between Sun rising and setting.

THEOREM.

THE Meridian of a Place passes thro' both the Poles of the Earth.

THERE are Meridians drawn on the Globe cutting every tenth or fifteenth Degree on the Equator; and the Meridian of Brals represents them all, *i. e.* if any Place is brought under it, it will be the Meridian of that Place.

IN right lined Maps the Meridians are strait Lines from the Top to the Bottom; but in curve lined Maps they are curve, and meet in the Poles.

9. THE *Azimuths* are great Circles intersecting each other in the *Zenith* and *Nadir*, as the Meridians do in the Poles of the World. Upon them is reckoned the Sun or Stars Altitude, but when the *Azimuth* of the Sun or a Star is spoke of, we are to understand the Angle which the *Azimuth* that the Sun or Star is in makes with the Meridian, either from the North or South.

10. CIRCLES of Longitude intersect each other in the Poles of the Ecliptic, and consequently cut it at right Angles as the Meridians do the Equator, because the Motion of the Sun, Stars, or Planets, whether according or contrary to the succession of the Signs *Aries, Taurus, Gemini, &c.* is reckoned upon the Ecliptic.

11. THE *Horizon* of a Place is a great Circle in the Heavens, which divides the visible Part of the Heavens from the invisible Part; and is called the *rational Horizon*, to distinguish it from the *visible Horizon*, which terminates our Sight round us; which is but a small Circle, and but improperly called the Horizon. It hath no fixed Place on the

artificial

artificial Globe; but the wooden Circle, which sustains the Globe and brass Meridian, represents every Horizon, when the Place is at the Top, as shall be shown; and 'tis called the *wooden Horizon*.

THESE Definitions are necessary to the understanding what follows. We must also know from Astronomy how the Sun and Stars move.

1. THAT is the first Motion common to them all, by which in twenty four Hours they go round the Earth when they rise, pass the Meridian, and set, and rise again; and they therein seem to describe every Day Circles parallel to the Equator; as moving all on the Axis of the Earth; and thus they move fifteen Degrees on the Equator, and every Parallel, every Hour; which is the twenty fourth Part of three hundred and sixty Degrees round, as appears by the horary Circle of Brass fixed on the Meridian, at the North Pole, whereon the Index points to the Hours, as the Globe revolves.

THE second, and proper, or annual, Motion of the Sun, is that by which the Sun (or the Earth) moves from West to East; which is against the first Motion. The Time or Number of Days in which the Sun returns to the Point from which it came, is called a Year; which is three hundred and sixty five Days, and about a quarter of a Day. The Path of this second Motion is called the Ecliptic, which is divided into twelve Parts, called Signs; for Astronomers have observed those Stars or Constellations of the Heavens, thro' which the Sun passes, and from these the twelve Signs receive their Names. And because they are all Animals, therefore the Ecliptic is called by the Antients the Zodiac. But properly the Ecliptic is in the middle of a Belt, which is sixteen Degrees broad; in which all the other Planets move

from West to East; some nearer, others further from the Ecliptic. The Names of the Signs are comprehended in these Verses:

♈ 10 March ♉ ♊ ♋ 11 June ♌ ♍
Sunt Aries Taurus Gemini Cancer Leo Virgo

♎ 10 Sept. ♏ ♐ ♑ 10 Decem. ♒
Libraque Scorpius Arcitenens Caper Amphora

♋
Pisces.

Arcitenens is also called *Sagittarius*, *Caper* *Capricornus*, and *Amphora* *Aquarius*. The Ecliptic cuts the Equator obliquely, and it's greatest Distance is about twenty three Degrees thirty Minutes; and where the Ecliptic cuts the Equator, which is in two Points, the Ecliptic begins at one of them, and the Sun in any one of these two Points makes the Days and Nights equal in all Places; and then Spring and Autumn begins; the Spring at the first of *Aries*, and the Autumn the first of *Libra*; and tho' two thousand Years ago the Signs were where the following ones are now, that is, they are gone backward, yet they retain their Names, without regard to the Stars they left.

EACH of these twelve Signs is divided into thirty Degrees and the Sun moves fifty nine Minutes eight Seconds each Day, by going thro' three hundred and fixty Degrees in the Ecliptic, in three hundred fixty five Days and a quarter; or we may reckon it a Degree in a Day: nor is there need for greater exactness in a small time, especially when the Design is only to instruct others. Likewise there being twelve Signs in the Ecliptic, and twelve Months in the Year, it goes thro' a Sign in a Month; but enters not the Sign in the beginning of the Month, but about the twenty first Day,

Day, according to the *Gregorian* Calendar, or the eleventh according to the *Julian*, viz. into *Aries*, *March* the tenth, and the tenth of *April* into *Taurus*, &c. or a little before, or after, the tenth Day. But if we would have the exact Knowledge of the Sun's Place it must be calculated from Tables, or taken from an *Ephemeris*: if one have a Globe it's Place may be nearly found on the wooden Horizon; if not, they may suppose the Sun enters each Sign on the tenth Day of the Month, and then count to the present time how much is gone since; but they must be well acquainted with the Signs, and know in what Month the Sun enters any Sign. Thus the fourteenth of *March* the Sun is in the fourth of *Aries*. Thus Students ought to know where the Sun is in the *Ecliptic*; for 'tis mean in a Man of Letters not to know so much, whilst the Seasons, and length of the Day and Night depends on the Sun's Place, and several other things that are useful in Life.





C H A P. XXIII.

Of the Latitude of Places, and the Elevation of the Pole.

PROPOSITION I.

The Latitude of a Place, is it's Distance from the Equator.

THIS Distance is measured by an Arch from the Place in the shortest way to the Equator, or an Arch of the Meridian of that Place, from the Place to the Equator.

BUT the Latitude of the Earth is it's Extension on the Superficies from one Pole to the other; and it's Longitude is it's Extension from the West by the East to the West again, which is the Equinoctial Line: but 'tis better not to mind these Terms in Geography.

PROPOSITION II.

The Elevation of the Pole above the Horizon of a Place is an Arch of the Meridian; between either Pole and the Horizon.

IT may be said, 'tis an Arch of the Meridian on the Earth, or in the Heavens; but 'tis better referred to the Earth, supposing the Earth to cause the first Motion; yet the Definition is referred by Astronomers

Astronomers to the Celestial Meridian; and the imaginary Pole there.

PROPOSITION III.

Having the Latitude of a Place on the Globe in Degrees and Minutes; if it be a large Globe; to find the same Latitude in Geographical Maps.

ON the Globe: bring the Place to the brass Meridian, and count the Degrees from it to the Equator, and it will be the Latitude sought.

IN Geographical Maps: if it be a right-lined one, draw a Line through the Place parallel to the Equator; and the ends of that Line on the Margin show the Latitude.

BUT if it be with Lines, and not any Line passing thro' the Place, fix one Foot of the Compass in the Place, and the other in the Pole of the Map; and describe a parallel Circle, which will cut the Degree of Latitude on the Margin that incloseth the Map, or on the Sides of it, if the other Parallels be described from the Pole, and at the same time you'll have it's Distance from the Pole.

PROPOSITION IV.

A Place being given on the Superficies of the Globe, how to place the Globe so as that the wooden Horizon may be the Horizon of the Place.

FIND the Latitude of the Place, and elevate the Po'e according to it; and then bring the Place to the brass Meridian, and it will be at the Top of the Globe; and therefore the wooden Horizon will be ninety Degrees from it every way.

PRO-

PROPOSITION V.

The Latitude of a Place is equal to the Elevation of the Pole above the Horizon of that Place; which is thus demonstrated.

LET C be the Center of the Earth, (Fig. 30.) and L the Place brought to the Top of the Globe or Zenith, and P the Pole, HPLZ will be the Meridian, HZ a Diameter of the Horizon, PH the Elevation of the Pole, and QT the Diameter of the Equator, where the Meridian and Equator cut one another; then PQ will be a Quadrant, or ninety Degrees, P being the Pole of the Equator; and also LH will be ninety Degrees, L being the Pole of the Horizon; then LH is equal PQ, and LP being taken from both, what remains, PH, LQ, will be equal.

COROLLARY.

THE Latitude of the Place being given, there is known the Elevation of the Pole.

PROPOSITION VI.

Having the Latitude of one Place, to find all the other Places that have the same Latitude.

ON the Globe: bring the Place to a Degree on the brass Meridian, and placing a Pencil there, turn the Globe, and the Pencil will describe a Circle passing thro' all the Places of the same Latitude.

AND in the Maps: draw a Line thro' the Place given that shall be parallel to the Equator, and it will go thro' all the Places of the same Latitude.

tude. But if it be a curvilinear Map, describe a Circle (whose Center is the Pole of the Map) that shall pass thro' the Place given; and find, as before, the several Places the Circle passes through. But if not the Place, but the Latitude is given, extend the Compasses from the Pole to that Degree of Latitude on the Side of the Map, and describe a Circle.

PROPOSITION VII.

To find a Meridian Line on a given Plane.

1. THERE are several ways; the easiest is to use a Magnetic Needle which will point North and South: but because in many Places it declines from the North, as we shall show, it will not do it accurately; but if the Declination of the Needle be known, as it is in the chief Places, it may be found accurately enough, drawing first the Meridian, which the Needle shows, and taking the Degrees of the Declination with the Compasses, set them to the East; if the Declination be westward; and, *vice versa*; then draw a Line from the Point they reach to the Center, and it will be a true Meridian.

THERE is no need of this Pains if you have a Mariner's Compass, wherein there is allowance made for all Declination in that Place for which 'tis made; for they that make the Instrument, put the *Flower de Luce*, which is the Sign of the North not just above the Needle; but so many Degrees from it as the Declination is.

2. BUT the Meridian Line is found better by the Stars. First, when the Sun shines, set up a Pin perpendicular to a Plane at twelve o'Clock, and the Shadow will show the Meridian. But
because

because the Hour is not exact enough; this way is not perfectly true.

3. SET a Pin perpendicular to a Plane in the Forenoon, and mark the length of the Shadow; and in the Afternoon mark again, when the Shadow is of the same Length, and draw a Line to the two Extremities of the Shadow, and bisect it by a perpendicular Line; which will be a meridian Line.

4. IF the Latitude of the Place be known, and the Sun's Altitude be taken, the meridian Line may be found by the Globe, thus: Draw a Line first on a Plane, and make it the diameter of a Circle, and the Line in which the Sun seems to be; then the Pole being elevated according to the Latitude; and the Sun's Place in the Ecliptic marked; and a Quadrant applied to the Top of the Globe, with the Sun's Altitude on it marked; then move the Globe and Quadrant both, 'till the Sun's Place and Degrees on the Quadrant meet; then see how many Degrees on the wooden Horizon between the brass Meridian and the Quadrant, and cut off so many on the Circle on the Plane, beginning at the end of the Diameter, either to the East or West, as the observation was made before or after noon, and draw a Line from the end of the Arch cut off, to the Center, and it will be a meridian Line. But it will be easier to observe the Line in which the Sun is seen either when rising or setting; and bringing the Sun's Place on the Globe to the wooden Horizon, see how many Degrees between it and the North or South, and turn the Line on the Plane so many Degrees about, and it will be a meridian Line.

PROPOSITION VIII.

To place the Globe so as the brass Meridian may be in the meridian Line.

FIND a meridian Line on the Plane, under the Globe, and turn it about 'till the brass Meridian be just above it. But this is done easier, if there be a Mariner's Compass under it, which shows the North and South Line.

THUS may Maps be placed also due North and South; of which there is use in Navigation.

PROPOSITION. IX.

To find the Latitude of a Place by the Sun or Stars.

THO' the Latitude is on the Earth, yet it cannot be found without the Sun or Stars.

1. OBSERVE how far the Sun is above the Horizon, or it's Distance from the Zenith at twelve o'Clock; then subtract the Sun's Distance from the Equator from the Zenith Distance, if the Sun be on the South Side of the Equator; but add it if on the North Side; and you have the Latitude. The Sun's Distance from the Equator, or the Declination, may be had from it's Place in the Ecliptic; or from Tables; or from the Globe, bringing the Place to the Sun under the brass Meridian, then counting how far it is from the Equator.

2. IF the Sun be rising or setting you may find the Latitude by the Globe. Find the Point the Sun is then in, by the Sea-Compass, which Mariners easily do, and find also the same Point on the wooden Horizon; and having the Sun's Place in the Ecliptic, then raise the brass Meridian

dian in the North of the wooden Horizon, or depress it 'till the Sun's Place set or rise on that same Point in the Horizon; and then see how much the Pole is elevated, and it will be the Latitude of the Place.

Note, This Method will not do in the time of the Equinoxes, when the Sun is in the beginning of *Aries* or *Libra*; for then the Sun sets and rises in all Places in one Point, *i. e.* West and East.

3. TAKE the Altitude of the Sun at twelve o'Clock by the help of the Length of a Style set perpendicular, and of it's Shadow, by which may be found the Angle at the Termination of the Shadow in the Triangle (*Fig. 31.*) ABC, that is, the Angle BCA; for as AB is to AC, so is the Sine of 90 to the Tangent of the Angle ABC, the Sun's Altitude; from which may be found the Latitude of the Place, as in the first Method; and if the observation be made at the Equinox, then the Sun's Distance from the Zenith is the Latitude.

THUS *Pliny* writes, *Chap. lxxii Lib. 2.* that *Rome* was found in Latitude 41 *degr. 25 min.* and *Carthage* in Latitude 32 *degr. 13 min.*

4. IN the Night-time, when the Stars are seen, if we take with an Instrument the Altitude of a Star in the Meridian, and know, from Tables, it's Declination; the Latitude may be found as if the Star were the Sun; as in the first Method: but if the Star be between the Pole and the Horizon, and the Declination North, the Complement of the Declination is to be added to the first Altitude, and it gives the Latitude.

IF the Star be between our Zenith, and the South Part of the Horizon; and the Declination North; add the Declination to the Complement

of the Altitude, and it gives the Latitude, as in the first Method.

5. I F the Point in which the Star rises or sets be observed, the Latitude may be found by the celestial Globe as before; supposing the Star to be the Sun.

6. I F you have not a Table of the Declination of the Stars, observe a Star that neither rises nor sets, *i. e.* a circumpolar Star, and observe it's Altitude at the highest and lowest; and take the half of the Difference, and add to the lesser, or subtract from the greater, and you have the Latitude.

7. T H E Altitude of the Pole-Star, will be the Latitude of the Place, if taken when two Degrees seventeen Minutes from the North, eastward or westward; but if it be at the highest, subtract two Degrees seventeen Minutes from it's Altitude; if at the lowest on the Meridian, add as much and you have the Latitude.

PROPOSITION X.

Places in the Equator have no Latitude, both Poles being in their Horizon; if at the Pole, the Place is ninety Degrees Latitude, and the Equator is then in the Horizon; and Places between the Pole and the Equator, have a Latitude less than ninety.

T H E S E are so plain as to need no Proof.

PROPOSITION XI.

If we are at Sea, or Land, and find our Latitude, we may see on the Globe that Parallel of Latitude in which we are.

T H I S is also plain.



C H A P. XXIV.

*Of the Division of the Earth into Zones, and
the Heavenly Appearances in those Zones.*

PROPOSITION I.

*There arises from the annual or diurnal Motion of
the Earth, a division of the Earth's Superficies in-
to five Parts, which we call Zones.*

FOR seeing the Sun describes by it's Motion
a Line called the Ecliptic, which cuts the
Equator in two opposite Points, and makes a De-
clination of twenty three Degrees thirty Minutes ; it
must be sometimes nearer, and sometimes further
from the Equator ; and thus changes the Seasons,
causing Heat, Cold, Rain, Wind, in the Places
it passes over.

THE Superficies of the Earth between the two
Tropics is called the *Torrid Zone* ; and those be-
tween the Poles and the polar Circles are the two
Frigid Zones ; and those between the polar Circles
and Tropics the two *Temperate Zones*, which make
five Zones ; that between the two Tropics, being
but one, is the *Torrid Zone*.

PROPO-

PROPOSITION II.

The Places whose Latitude is less than twenty three Degrees thirty Minutes lie in the Torrid Zone, and if just twenty three Degrees thirty Minutes, they are under the Tropics, or at the end of the Torrid Zone. Those that have a less Latitude than sixty six Degrees thirty Minutes, and greater than twenty three Degrees thirty Minutes, are in the Temperate Zone. Those that are in the Latitude sixty six Degrees thirty Minutes, are at the end of the Temperate Zone; and if, in a greater Latitude, they are in the Frigid Zone. As in Chap. 23.

ALL this is manifest.

PROPOSITION III.

The Equator passes thro' the Isle of St Thomas in the great Bay of Africa, called the Ethiopic Sea; and thro' Ethiopia in the South Part of Africa; thro' the Indian Ocean; thro' the middle of Sumatra, or Taprobane, and the golden Chersonesus, or Peninsula of Malacca, and other Islands in the Indian Ocean; and thro' the Moluccas, thro' the Pacific Sea, and the beginning of the Province of Peru; thro' the Lake Parime; and thro' the Atlantic Ocean to the Isle of St Thomas.

THE Equator divides the Torrid Zone into two equal Parts; which might be called two Torrid Zones, one North, the other South.

IN the Torrid Zone lie, 1. a great Part of Africa, Abassia, the Indian Sea, a Part of Arabia, Cambodia, India, and the Isles of the Indian Sea, Java, Ceylon, Peru, Mexican-Spain, a great Part of the

Atlantic Ocean, the Isle of St Helena, Brazil, and New Guinea.

THE Tropic of *Cancer* passes a little beyond Mount *Atlas*, in the western Shore of *Africa*, thro' the Borders of *Libya*, and other Places in the middle of *Africa*, and thro' *Syene* in *Ethiopia*, and goes over the *Red-Sea*, and beyond *Sinai* and *Mecca*, the *Mabometans* Country, and *Arabia the Happy*, and then enters the *Indian Sea*, and touches the Bounds of *Persia*, and goes thro' *Cambaya*, *India*, *Camboia*, or the Bounds of the Kingdom of *Siam*, 'till it comes to the *Pacific Sea*; and having passed that, below the *American Chersonesus* and *California*, it goes to the Kingdom of *Mexico*, and then to the *Atlantic Ocean*, and touches the Shores of the Isle of *Cuba*, and then returns to the West Shore of *Africa*.

THE Tropic of *Capricorn* passes thro' but a few Places of the Earth; most part of it goes over the Sea; first, thro' the South Part, or the *Tongue* of *Africa*, *Monomotapa*, *Madagascar*, in the *Indian Ocean*, *New Guinea*, the *Pacific Ocean*, *Peru-Brazil*, and the *Atlantic Ocean*.

IN the North *Temperate Zone* are many Places almost all known and inhabited, viz. all *Europe*, *Asia*, (except the golden *Chersonesus*, and the Isles in the *Indian Sea*) and a great part of North *America*, and of the *Atlantic* and *Pacific Sea*.

IN the South *Temperate Zone* are few Places, and those not all known, but chiefly there is Sea there, viz. a Part of South *Africa*, of *Monomotapa*, the Cape of *Good-Hope*, a great Part of the *Magellanic*, or South Land, a Part of *Brazil*, *Chili*, the *Magellanic Streights*, and a great Part of the *Atlantic*, *Indian*, and *Pacific Sea*.

THE arctic polar Circle passes almost thro' the middle of *Iceland*, the North Part of *Norway*, thro' the North Ocean, *Lapland*, and the *Russian*

Russian Bay, Samoeids Country, Tartary, North America, and Greenland.

THE polar antarctic Circle passes thro' the South, or *Magellanic Land*, of which we know nothing.

IN the North *Frigid Zone* are one half of *Iceland*, the North Part of *Norway* and *Lapland*, *Finmarc*, *Samoeida*, *Nova Zembla*, *Greenland*, *Spitzberg*, and some northern Parts of *America* unknown.

IN the South *Frigid Zone* there is either Land or Sea, but we know not which. These are all shown by the Globe or Maps, and are proved by the Tables of Latitude made by Observations.

PROPOSITION IV.

The Places under the Tropics have only the Sun once a Year in their Zenith, and those in the Torrid Zone twice in the Year, or two Days equally distant from the longest Day; but those beyond the Tropics, and without the Torrid Zone, have never the Sun in their Zenith.

FOR the Sun, being in the first Degree of *Cancer*, goes thro' the Tropic of *Cancer* in the Heavens, under which the same Tropic on the Earth lies; and therefore the Sun goes over them, and the same Way as to the Tropic of *Capricorn*; as will appear in the Globes and Maps.

BUT in the *Torrid Zone* the Sun comes twice over them in a Year. Bring any Place there to the brass Meridian, and applying a Pencil, describe a Circle parallel to the Equator; which will cut the Ecliptic in two Points equally distant from the Tropics: and the Sun in these two Points will then be vertical to the given Place at Mid-day, and on no other Days.

AND lastly, it can never be vertical to the Places in the *Temperate Zone*, because no parallel described by the Sun goes over these Places ; and so it is as to the *Frigid Zones*.

PROPOSITION V.

The Sun doth not set nor rise for some Days to those in the Frigid Zones ; and the more those Days are, the nearer the Place is to the Pole ; so that at the Pole it sets not for half a Year, and rises not all that time : and those in the very arctic and antarctic Circle have one Day wherein the Sun sets not, and another wherein it rises not ; but at other times it rises and sets.

TAKE a Place in the *Frigid Zone*, and elevate the Pole according to it's Latitude, and applying a Piece of Chalk, or a Pencil, to the North of the Horizon ; that is, next the Pole ; describe therewith a Parallel, by turning the Globe round, which will cut the Ecliptic in two Points, into which, and the intermediate Points, when the Sun comes it sets not : for all the Parallels thro' these Points keep above the Horizon in the Rotation of the Globe. And if applied to the opposite Notch, and a parallel Circle be described, it will pass thro' two Points of the Ecliptic ; into which and the intermediate Points, when the Sun comes it rises not above the Horizon ; but it will be otherwise if the Place be taken in the other *Frigid Zone*. And so as to those Places in the arctic and antarctic Circle, if the Globe be elevated to sixty six Degrees thirty Minutes, and the Globe revolved, the first of *Cancer* will then just touch the Horizon, and not set ; and so will the first of *Capricorn* without rising above it ; but in the other Degrees of the Ecliptic it will set and rise.

PROPO-

PROPOSITION VI.

The Sun rises and sets every Day to all Places in the Temperate and Torrid Zones.

TAKE any Place in these Zones, and elevate the Pole to it's Latitude, so as the wooden Horizon may be the Horizon of that Place; then turning the Globe, you'll see all the Points of the Ecliptic rise and set: and so must the Sun in these Points.

PROPOSITION VII.

Having a Place in the Torrid Zone, to find the two Days in which the Sun is vertical to it.

BRING the Place to the brass Meridian, and observe the Degree of it's Latitude, and turn the Globe 'till you find the Ecliptic pass under that Degree in two Places, into which when the Sun comes it will be vertical to that Place; then find what time, or Day, of the Year the Sun comes to these two Points, from Tables, or from the wooden Horizon, or by the Method Chap. 22.

'TIS also plain in the Universal Maps; for drawing a Line thro' the Place, parallel to the Equator, it will cut the Ecliptic in two places also; from which the two Days may be known.

BUT, without Globes and Maps, you may find the Latitude of the Place, in Degrees, and look in the Table of Declination for the same Number of Degrees of Declination, and you'll have the two Days answering thereto.

Note, The Sun's Center, which is sixteen Degrees from it's Circumference, will be a few Days sooner, or later, vertical to the Place, than the Cir-

cumference, in it's North or South Point at Mid-day.

PROPOSITION VIII.

A Place being given in the Frigid Zone, to determine the Days in which the Sun doth not set there, nor rise, and when those Days begin and end.

ON the Globe. Let the Place be brought to the Meridian, and the Pole elevated to it's Latitude; then, turning the Globe round, observe the two Points in the Ecliptic which do not set, or go under the Horizon; the first, that is next to *Aries*, shows the first Day of it's not setting, and that next *Libra* the Day when it begins to rise, and the two Days in which the Sun is in those Points the Sun will only touch the Horizon, and it's Center will be a little above it; and thus the Days are found in which the Sun will be under the Horizon in the opposite Part of the Year.

THIS may be done easier by the Globe, tho' the reason of it is not so obvious. Find the Complement of the Latitude of the Place, and count so many Degrees from the Equator, and mark what Points of the Ecliptic come under that Degree on the Meridian, and they will be found to be two Points into which, or the intermediate Points, when the Sun comes, it will not set: and so you have an Arch, at the South, which shows how long 'tis under the Horizon.

AFTER the same way in the Maps; draw a Line thro' the Degree, that is as far from the Equator as the Place is from the Pole, and you'll see what Point it cuts in the Ecliptic; in and between which when the Sun comes it doth not set: and in the South part you see how long 'tis under the Horizon.

IF

IF the Latitude of the Place be known, find the same Degree and Minute in the Table of Declination, and against it you'll have the Day in which it begins and ends the not setting; and other two Days that have the same South Declination in which it begins and ends the not rising; the first will be between the twenty first of *June* and the first of *March*; the other between the twenty first of *June* and the twenty first of *September*; and one of the last between the twenty first of *September* and twenty first of *December*; the other between that, and the twenty first of *March*.

THIS is to be understood of the Sun's Center which is sixteen Minutes above and below the Limb.

PROPOSITION IX.

Having the Day of the Year, to find those Places in which the Sun will then be vertical.

FROM the given Day, find the Sun's Place in the Ecliptic as in *Chap. 22*.

BRING the Sun's Place in the Ecliptic under the Meridian, and mark the Degree above it; and turning the Globe, observe all the Places that pass under that Degree will have the Sun vertical one after another: and in the Maps find the Sun's Place in the Ecliptic, and draw a Line parallel to the Equator, either straight or curve, as the Map is, and all the Places it passes over are those sought.

BY the Table of Declination find the Degree of Latitude of those Places, or, which is the same, the Degree of Declination that Day; which being found, you'll have the Places by drawing a Line thro' those Degrees.

PROPOSITION X.

Having the Day of the Year, to find those Places in which the Sun begins then not to set and not to rise.

THE given Day must be between the twenty first of *March* and twenty first of *June*, or twenty first of *September* and twenty first of *December*.

FIND first the Sun's Place for that Day, which bring to the Meridian; and as many Degrees as are between it and the Equator, count so many from the Pole towards the Equator; and draw a parallel Circle at that Distance from the Pole: all the Places within it will show the first, *i. e.* the Sun's not setting there; and the like being drawn as near the other Pole, will include the Places where it does not rise; and the Places under the two Parallels show where these two Changes begin. Then,

TO show the Truth of it; elevate the Pole according to the Latitude of any of the Places; and it will appear when the Sun's Place in the Ecliptic begins not to set; and how long it continues so; and when it begins not to rise in the South Part. The same may be done by the Maps; taking the Declination of the Sun, which will reach from the Pole to the Parallel in which the Sun begins not to set: and so likewise at the South.

AND by the Table of Declination you have the Latitude of the Places sought for.

PROPOSITION XI.

To calculate the Breadth and Quantity of each Zone in Miles, or any known Measure.

THE

THE Breadth of the *Torrid Zone* is 47 Degr. *i. e.* 23 Degr. 30 Min. on each side of the Equator. The Breadth of each *Temperate Zone* is 86 Degr. and of both *Frigid Zones* 27 Degr. which Degrees, if turned to Miles, counting each Degree 15 German Miles, the Breadth of the *Torrid Zone* will be 705 Miles. And one of the *Temperate* 645, and one of *Frigid* 352 $\frac{1}{2}$. And the Superficies of each is known by this Proportion from Geometry; as the Sine of 90 Degr. 1000000 is to the Sine of 23 Degr. 30 Min. *viz.* 39875; so is half the Superficies of the Earth found in Chap. 4. to be 4639090 square Miles to the Superficies of half the *Torrid Zone*, *i. e.* 1849837 square Miles; and therefore the Superficies of the whole *Torrid Zone* is 3699674 Miles.

THEN as the whole Sine 1000000 to the Difference of the Sines of 23 Degr. 30 Min. and 66 Degr. 30 Min. 51831; so is the half Superficies of the Earth or 4639090 square Miles, to the Superficies of one of the *Temperate Zones* 2404487 square Miles. If therefore you subtract the Superficies of half the *Torrid Zone*, and that of the *Temperate Zone*, from half the Superficies of the Earth, there remains the Superficies of one of the *Frigid Zones* 384766 square Miles. Some Astronomers are of Opinion, that the Declination of the Ecliptic is not always the same; and therefore the Bigness of the Zones is not always the same; but the Difference is small: and *Tycho* doubted if there was any. We need not mind it here.

WE might have treated of the different Seasons in different Places; but because there are some things in the following Chapter that will help us to make a better Judgment thereof, I thought it best to defer it.



C H A P. XXV.

Of the Length of the Day in different Places of the Earth, and the Division of the Earth into Climates, which arises from thence.

PROPOSITION I.

The Days and Nights are of the same Length twice in the Year in all Places.

THESE Days are when the Sun is in the Equator, *i. e.* in the first of *Aries* and *Libra*, on the twenty first of *March*, and twenty first of *September*, according to the *Gregorian* Calendar; which Days have twelve Hours Day, and twelve Hours Night, in all Places, counting the time the Sun is above the Horizon for a Day.

TAKE any Place on the Globe, and elevate it according to its Latitude, or bring the Place to the Zenith; then bring the Sun's Place to the Horizon in the East, and the Index of the horary Circle to twelve, and turn the Globe; you will find it will describe twelve Hours while the Sun's Place is going to the Horizon in the West: it appears further from the Horizon's cutting the Equator into two equal Parts. We might show it the same way, whatever Place of the Earth be chosen. And the two Poles do those two Days neither rise nor set, and they have there Night and Day at once; in other Places it turns from Day to Night in an Instant, but there they last together for a whole Revolution; the one half of the Sun being above,
and

and the other below the Horizon. On the twenty first of *March* begins a Day of six Months, and on the twenty first of *September* a Night as long; and we may say, 'tis both Day and Night for twelve Hours at the Pole. There are other things peculiar to that Place.

1. THE Sun only rises and sets there once in a Year, it rises the twenty first of *March*, and sets the twenty first of *September*.

2. THEY have no Mid-day and Mid-night at a set Time; their Mid-day being at all Times for six Months, and the other six 'tis always Mid-night.

3. NO fix'd Stars rise, and none set, but some are always under, others always above; the former of which being never seen by the Inhabitants, if any there, which is not likely; the latter always seen for six Months if the Weather be clear when the Sun is under the Horizon.

4. THE Stars and the Sun keep almost the same Altitude all Day.

5. NO Wind can be called there, northerly; they being all from the South; and in the other, the South Pole, they are all northerly.

6. IF the Sun and Stars move not according to *Copernicus*, but the Earth, and the Eye, be a Point placed in the Pole, all the Stars, and the Sun and Moon, would appear immoveable in the same Place.

PROPOSITION II.

In Places under the Equator the Days and Nights are always equal; and at the Poles there is but one Day and Night in the Year; tho' the Day at the North Pole is longer than at the South Pole.

TAKE

TAKE any Place on the Globe under the Equator, and any Day of the Year, and mark the Sun's Place that Day, and bring the Place to the Zenith, the Poles being in the Horizon; and it will appear, that that Place, in a Revolution of the Globe, will be as long above as under the Horizon, supposing it's apparent Motion equal, as indeed it is. And as to the other Part of the Proposition; bring the Pole to the Zenith, the one half of the Ecliptic will be above, the other below the Horizon, but the Sun will be longer above than below, for it really moves in an *Ellipsis* whose *Focus* is out of it's Center; or the Earth does so, which makes the same Appearance: there are one hundred eighty seven Days it continues above, and one hundred seventy eight below; which makes the Day about nine Days longer than the Night.

PROPOSITION III.

There are no Days equal except two in the Places between the Equator and the Pole.

TAKE any Place, and elevate the Pole according to it's Latitude, and taking any Day, except those two of the Equinoxes, and mark the Sun's Place in the Ecliptic for that Day; turn the Globe and you will see the Mark will be longer above than below the Horizon, if the Day be between the twenty first of *March*, and twenty first of *September*; but if not, it will be longer below the Horizon: and the Difference will be the greater, the further the Sun is from the Equator.

OR bringing the Sun's Place to the East Horizon, and the Hour Hand to twelve, you will see, in turning the Globe, the Hours of the Day 'till the Sun set in the West; and it's Continuance under the Horizon.

PROPOSITION IV.

A Place being given, and it's Latitude, to find the Length of the Day at any Time.

FIND the Sun's Place at that time in the Ecliptic, and elevate the Pole to the Latitude of the Place, bring the Sun's Place to the East Horizon, and the Hour Hand to twelve; you will see how many Hours the Sun's Place will take to come to the West Horizon; and subtract them from twenty four, and you have the Length of the Day.

PROPOSITION V.

In all Places between the Equator and North Pole, the Day is longest when the Sun is in Cancer, and shortest when in Capricorn; but in those Places between the Equator, and the South Pole the contrary happens; that is, when the Sun is in Cancer, the Days are shortest, and when in Capricorn longest.

TAKE a Place at Pleasure, and elevate the Pole according to it's Latitude; find, by the preceding Proposition, the Number of Hours in the Day, when the Sun is in the first of *Cancer*; and find also the Number of Hours for another Part of the Ecliptic, which will be found less, whatever other Part of the Ecliptic be taken.

THE same way it may be shown, that the Day is shortest when the Sun is in the first of *Capricorn*. And the same Method may be taken when the Sun is on the other Side of the Equator.

COROL.

COROLLARY.

A Place being given, or it's Latitude, to find the Length of the longest Day: find, as before, the first of *Cancer*, and find the Hours it continues above the Horizon, by the preceding Proposition.

PROPOSITION VI.

The Days encrease continually in the northern Places while the Sun moves from the first of Capricorn to the first of Cancer, i. e. from the twenty first of December, to the twenty first of June; but the contrary way in South Places, i. e. when it moves from Cancer to Capricorn, or from the twenty first of June, to the twenty first of December.

TAKE any Place on the North Side of the Equator, and elevate the Pole for that Latitude; and take two or more Places in the Ecliptic, and you will find that which is nearest the first of *Cancer* keeps longest above the Equator: and the same will happen as to those Places on the South Side of the Equator; if the South Pole were elevated to the Latitude, those Degrees nearest the first of *Capricorn* would be longer above the Horizon.

PROPOSITION VII.

If one Place be further from the Equator than another, the difference of the longest and shortest Day, and between Day and Night, will be greater there; so as that the Places near the Equator have the longest and shortest Day, and Days and Nights but little different. They at the North Tropic have only two Hours Difference between the longest and shortest Day; and their Days and Nights nearly equal.

THIS

THIS will easily appear by taking two Places, one more northerly than the other, and finding the Length of the Day, at two Times of the Year; for one Place, and for the same Times in the other Place; and also the Difference of the Day and Night at that time, and you will find the Difference greatest in the Place of greater Latitude, both as to the Day and Night, and the longest and shortest Day.

PROPOSITION VIII.

All the Places in the same Parallel have all their Days equal, and therefore their longest Day equal.

FIRST elevate the Pole according to the Latitude of any Parallel; then take two Places in that Parallel, and bring the one to the Meridian, and observe how much of it is below, and how much under the Horizon; then bring the other to the Meridian, and observe the same, and you will find the Difference the same in both. This might be also shown by the horary Circle.

FROM these Things may be easily understood the Division of the Earth into Climates.

A Climate is the Space included by two Parallels, between the Pole and the Equator, into which when the Sun comes, there is the Difference of half an Hour, as to the Length of the Day; in which we may observe the beginning of Climate in the Parallel nearest the Equator, and the middle when the Day becomes a Quarter longer, and the end in the Parallel from the Equator, which is the beginning of the next Climate.

PROPOSITION IX.

If we take several Places, whose Parallels are equally distant, their longest Days will not exceed one another

ther equally; the Difference being greatest where they are most distant from the Equator.

TAKE first one Parallel, and raise the Pole to that Latitude, and observe the Continuance of the first of *Cancer* above the Horizon; then raise the Pole to the Latitude of another Parallel that is ten Degrees from it, and observe the Continuance above the Horizon there, and so for another thirty Degrees, and forty Degrees; the Continuance of the first of *Cancer* above the Horizon, will not exceed one another equally.

AND what is said of the longest Day, or the first of *Cancer*, will hold as to any other Day or Degree of the Ecliptic.

PROPOSITION X.

If in several Parallels the longest Days exceed one another equally, these Parallels will not be equidistant; and those further from the Equator will be nearer together.

THIS may be shown by the former; for if they were equidistant, the Days would not equally exceed one another as is supposed.

PROPOSITION XI.

Having the Length of the longest Day in any Place, to find the Latitude of that Place.

BRING the first of *Cancer* to the Meridian, and the Index to twelve, and turning the Globe 'till the Index point to the Hour as far distant from twelve as the Day is long; and mark the Point of the Tropic under the Meridian, then bring the first of *Cancer* to the East Horizon, and elevate the
Globe

Globe 'till you mark the Tropic in the West Side of the Horizon, and the first of *Cancer* in the East Side, and the Degrees of Elevation show the Latitude.

THIS Proposition may be made more general thus ; having the Length of the Day in any Place, to find it's Latitude. This may be solved the same way, only for the Tropic take a Parallel that goes thro' the Sun's Place that Day.

C O R O L L A R Y,

THE Latitude of the Parallels of each Climate may be thus easily found ; for Example, in the end of the first Climate, the Length of the Day is twelve Hours and a half, and of the second thirteen Hours, &c.

P R O P O S I T I O N XII.

Having any Number of Days less than half a Year ; to find the Latitude of that Parallel where the Sun shines so long to them, and where 'tis hid from them so long.

T A K E half the Number of Days, and count so many Degrees from the first of *Cancer* on the Ecliptic, and mark where they end, and count from the Mark to the Pole, and you have the Latitude of that Place where the Days and Nights will be of such a Number of Days.

F O R if you raise the Globe to the Latitude found, you will see that Point in the Ecliptic, dip at the North Part of the Horizon ; and all the Points between that and *Cancer*, and as far beyond it, will keep above the Horizon ; and so the Sun in them doth not set.

C O R O L L A R Y.

THUS 'tis easy to find the Latitude of the Climates in the *Frigid Zones*, where the longest Day increases by some Days.

P R O P O S I T I O N XIII.

To make a Table of Climates.

THAT is, to find the Latitude, and the longest Day at the beginning, middle, and end, of each Climate; and the Distance of the Parallels. First add still to twelve a Quarter of an Hour; and you have the increase of the Day for that Climate; then from that Length of Day find the Latitude by *Prop. II.* and, for the Distance of the Parallels, subtract the Latitude at the end of the one Parallel, from that at the end of the next, more northerly. The same way the middle of the Climate is found by adding a Quarter to twelve; and find the Latitude for that by *Prop. II.* We here add a Table of Climates and Parallels.

A Table of Climates and Parallels.

Climates Parallels		Longest Day		Latitude		Interval	
		Hours	Min.	Degr.	Min.		
1	Begin.	12	0				
	Middle	12	15	4	15	4	15
	End	12	30	8	25	8	25
2	Middle	12	45	12	30		
	End	13	0	16	25	8	
3	Middle	13	15	20	15		
	End	13	30	23	50	7	25
4	Middle	13	45	27	40		
	End	14	0	30	20	6	30

Climates

Climate	Parallels	Longest Day		Latitude		Interval
		Hours	Min.	Degr.	Min.	
5	Middle	14	15	33	40	6 8
	End	14	30	36	28	
6	Middle	14	45	39	2	4 54
	End	15	0	41	22	
7	Middle	15	15	43	32	4 7
	End	15	30	45	29	
8	Middle	15	45	47	20	3 32
	End	16	0	49	1	
9	Middle	16	15	50	53	2 57
	End	16	30	51	58	
10	Middle	16	45	53	17	2 29
	End	17	0	54	27	
11	Middle	17	15	55	34	2 10
	End	17	30	56	37	
12	Middle	17	45	57	32	
	End	18	0	58	29	
13	Middle	18	15	59	14	
	End	18	30	59	58	
14	Middle	18	45	60	40	
	End	19	0	61	18	
15	Middle	19	15	61	55	
	End	19	30	62	25	
16	Middle	19	45	62	54	
	End	20	0	63	22	
17	Middle	20	15	63	40	
	End	20	30	64	6	
18	Middle	20	45	64	30	
	End	21	0	64	49	
19	Middle	21	15	65	6	
	End	21	30	65	21	
20	Middle	21	45	65	35	
	End	22	0	65	47	

Climates Parallels		Longest Day		Latitude		Interval
		Hours	Min.	Degr.	Min.	
21	Middle	22	15	65	57	
	End	22	30	66	6	
22	Middle	22	45	66	14	
	End	23	0	66	20	
23	Middle	23	15	66	25	
	End	23	30	66	28	
24	Middle	23	45	66	30	
	End	24	0	66	31	

THEY use not to carry the Table further ; for, in the Places following, the longest Day increases not by Hours, but by whole Days ; and the following Canon will shew the Latitude where it increases even by Months.

Months.	1	2	3	4	5	6
D. M.						
Latitude	67 30	69 30	73 20	78 20	84	90

PROPOSITION XIV.

To explain the Method of other Geographers in enumerating the Climates, and making the Table.

THE antient Geographers, especially the Greeks, thought there was but a small Portion of the Earth inhabited ; thinking the northern Places, and the *Torrid Zone*, could not be inhabited ; and therefore they divided only the Part they knew into Climates, and counted only six of them from the Equator to the arctic Pole, which they named from some remarkable Place in their Middle.

THE

THE first was thro' the Isle of *Meroe*, in *Africa*, or the City so called, which is surrounded with the *Nile*.

THE second thro' *Syene*, a City in *Egypt*.

THE third thro' *Alexandria*, a Sea-Port in *Egypt*.

THE fourth thro' the Island *Rhodes*, in the *Mediterranean*.

THE fifth thro' the *Hellespont*, others thro' *Rome*.

THE sixth thro' the *Borysthenes*, a famous River in *European Sarmatia*.

THE seventh thro' the *Riphaean* Mountains of *Sarmatia*.

THEY did not count any Climates to the South, which was unknown, and which many thought was all Sea ; but others after them thinking that unlikely ; they did also count Climates on the other Side of the Equator ; not from remarkable Places, for they knew none there ; but called them, as the North Climates are, with the Proposition *Anti* before them ; as the Climates against *Meroe*, or *Syene*, &c.

AND when they understood that more Parts were inhabited, they made more Climates ; some named the eighth Climate from the Lake of *Mæotis*, the ninth from the *Baltic* Sea, &c. which Names tho' they are not necessary in the Construction of the Table, yet may be added to our Table where we place the Number of Climates ; thus we shall better remember the Climates, and the Places in each Climate, and may compare the Degrees of Heat and Cold in them : which we chuse rather to leave to the Industry of the Readers, that they be the better acquainted with the Globe.

MOREOVER, they did not begin at the Equator as we do, but at the Place where the longest Day is twelve Hours three Quarters, and

so their first is the second in ours, and their second our third ; for they reckoned that the Places under nine Degrees of Latitude could not be inhabited for the Heat there ; but the contrary being found, we could not assent to their Method. *Ptolemy* begins the first Climate where the longest Day is twelve Hours and a Quarter, or the Latitude four Degrees fifteen Minutes. 'Tis no great Matter, yet 'tis better to begin at the Equator, that all Places may be in some Climate.

PROPOSITION XV.

To show the Use of the Table of Climates.

1. **HAVING** the Latitude of a Place, to know it's longest Day, and it's Climates. Find the Latitude in the Table, and over against it you have the longest Day, the Climate, and Parallel ; if the Latitude is not in the Table, take the next above, and below it.

2. **HAVING** the Length of the longest Day in any Place, to know the Latitude and Climate in that Place. Find the longest Day, and against it you have both.

3. **HAVING** the Climate, to find the longest Day. This is easily found in the Table.

C H A P.



CHAP. XXVI.

Of Light, Heat, Cold and Rains in the different Zones, and other Properties belonging to the several Zones.

PROPOSITION I.

The Causes that most contribute to make Light, Heat, Cold, Rains, and other Meteors, and to preserve them in several Zones, and the neighbouring Places, are :

1. **T**HE greater or less Obliquity, or Perpendicularity of the Rays that come on the Place. The last of which make the greatest Heat, and the other two make more or less Heat in proportion to their Obliquity.

2. **T**HE Continuance of the Sun above the Horizon of the place.

3. **T**HE greater or less Depression of the Sun under the Horizon in the Night ; which causes more or less Light, Heat, Rain, thick Clouds, &c. From this comes more or less Twilight.

4. **T**HE Continuance of the Moon, for more or less time above or under the Horizon ; and it's greater or less Elevation above it, or Depression under it.

5. **T**HE same may be said of the fixed Stars, especially the more remarkable ; and of the five Planets, *Saturn, Jupiter, Mars, Venus, Mercury* ; for they all cause some small Light and Heat in the
Air,

Air, and change the Air various Ways, and excite Vapours in it, as Astrologers tell us.

6. THE Kinds of the Earth that are in several Places ; for where the Earth is rocky or stony, there the Air is for the most Part colder than where 'tis fat and sulphureous, and not so fertile ; or where there is much Sand and no Rivers there is much Heat and Drought.

7. ADJACENT Seas or Lakes ; from thence come a great many moist Vapours into the Air ; and the Rays are not so strongly reflected from the Sea as from the Land.

8. THE Situation of Places ; for the Sun influences the Mountains and Vallies differently, and the Rays are kept from the Plains oftentimes by the Mountains, which do also in some manner draw the Vapours to them, as we said *Chap. 20.* Whence 'tis the Mountains change the Seasons of the neighbouring Places ; causing Heat, Rain, &c. which would not be if the Mountains were not there.

9. THE Winds, especially the general and stated ones ; thus the stated easterly Winds temper the Heat of the *Dog-Days*, and the general Wind in the *Torrid Zone*, especially the East Winds in *Brasil* cause a moderate Heat there : whilst there is a vehement Heat in the West of *Africa* ; for in these Places the general Wind is not so sensible. The North Winds are cold and dry. The South Winds are hot and moist with us.

10. THE Clouds and Rain lessen the Light and Heat.

THESE are, I suppose, all the Causes of the Changes that happen as to Light, Heat, &c. either in the same, or different Places, at different, or the same times.

P R O P O.

PROPOSITION II.

How the Seasons of the Year, as Spring, Summer, Autumn, and Winter are to be defined.

ALTHO' we are not, in treating of the Sciences, to dispute about the Definitions of things; yet, because the Signification of some Words is dubious; we must explain them here, to avoid Confusion, and that Students may not be entangled and deceived with different Meanings.

THE Question includes two Difficulties; 1. Whether the Seasons are determined by the Sun's Entrance into, and continuing in, certain Signs of the Ecliptic, as Astronomers generally suppose, calling it Spring when the Sun enters the first of *Aries*, which continues 'till it enters the first of *Cancer*, and making it Summer 'till the Sun moves from that to the first of *Libra*; and Autumn 'till it come to the first of *Capricorn*; and Winter 'till it come to the first of *Aries* again.

'TIS evident that these Definitions are not true in all Places, but only in those to the North of the Equator; for in the South Places they have Spring while the Sun is between the first of *Libra*, and the first of *Capricorn*, and Summer from that to the first of *Aries*; and so on the contrary to the former: and one may think the Seasons cannot be explained in a Sense agreeable to all Places, and yet they may and ought to be. Moreover, the Definitions above do not agree to Places in the *Torrid Zone*; for when the Sun passes over them it must be allowed to be Summer there (except some other Cause alter it); with respect to the Heavens, and in Places on the Equator, it ought not to be either Spring or Autumn when the Sun is past the first of *Aries*, but Summer, for then the Sun is passing over

over them, and so making the greatest Heat to them : nor can that Summer be transferred to the first of *Cancer*, or *Capricorn*. And the same may be said of Places between the Equator and Tropics, because the Sun passes over them also before it comes to the first of *Cancer* or *Capricorn*, and so makes Summer first. For it must be known, that tho' Definitions are arbitrary, yet all agree in making the Summer to be caused by Heat, and the Winter by Cold, or less Heat ; and Definitions must be so framed, as to agree in part with these Notions, or not to be repugnant to them ; and there is the same Difficulty as to Spring and Autumn in the *Torrid Zone* ; whilst there seems to be none at all, especially at the Equator.

THE second Difficulty which made the Question be proposed is, *whether the Seasons are to be determined from the Degree of Heat and Cold, or from the Sun's approaching, or withdrawing ?* for the common Notion of the *Europeans* of the Seasons includes them both, especially the Cold and Heat, tho' Astronomers have most regard to the Sun's Place in the Ecliptic. Moreover, 'tis found in many Places in the *Torrid Zone*, that the Seasons do not answer the Sun's coming to them, or going from them, but that they find it Winter (abounding not indeed with Cold, but with Rains and Storms) when it should be Summer, by the Sun's being nearly above them ; and on the contrary, they find it Summer when the Sun goes from them, and they should rather have Winter ; of which strange thing we shall give Examples afterwards. And therefore they make their Summer to consist in a clear Sky ; and their Winter in wet Weather, with a little Cold. And therefore the Notions of the Seasons differ much according to the Places.

AFTER

AFTER considering these Difficulties, I am of Opinion ; 1. seeing in several Places of the *Torrid Zone*, as was said in the second Difficulty, and also in some Places in the *Temperate Zone*, Heat and Cold have no regard to the Sun's Motion ; nor are we to think that Heat and Cold makes the Seasons, except we distinguish between Seasons of the Heavens and of the Earth ; which Words we must use for want of better : hence the terrestrial Summer Season of a Place, is the Time of Year when there is greatest Heat there ; but the celestial Summer is the Time when one might expect the greatest Heat from the Sun's nearness ; and the like may be said of the Winter Season : and tho' in several Places the celestial and terrestrial Summer and Winter happen at one Time of the Year ; yet in some Places of the *Torrid Zone* they are in different Times of the Year, as shall be showed hereafter. And the same is to be said as to the celestial and terrestrial Spring and Autumn.

2. SEEING there are but few Places where the terrestrial Summer and Winter differ from the celestial, as to the time of Year, they happening in most Places at the same time of the Year ; therefore the celestial Summer may be called simply the Summer, and so the terrestrial Spring, the Spring, &c. and when we would speak of the terrestrial Summer or Winter we shall call them Terrestrial, to distinguish them from those absolutely called Summer and Winter, when the Celestial and Terrestrial agree.

THE celestial Summer of a Place is when the Sun comes nearest to it's Zenith ; and Winter when furthest from it ; and Spring is between the end of Winter, and beginning of Summer ; and Autumn between the end of Summer and beginning of Winter. And these four Seasons may be thus understood in all Places.

PROPOSITION III.

The celestial Summer of those Places between the North Tropic, and the North Pole, begins when the Sun enters the first of Cancer, on the twenty first of June, and ends, when it enters the first of Libra, on the twenty first of September ; and at the same Time in all those Places. And 'tis Autumn with them when the Sun goes from the first of Libra to the first of Capricorn, and Winter while 'tis between the first of Capricorn, and the first of Aries.

THE Truth of this Proposition appears from the foresaid Definitions, and may be easily shown on the Globe and Maps ; for the Sun is least distant from the Zenith when in the Tropic of *Cancer* ; and is at a mean Distance when between the first of *Libra* and *Capricorn*.

THE Summer Places between the South Tropic and the Pole, which takes in the *Temperate* and the *Frigid Zone*, begins when the Sun enters the first of *Capricorn*, and ends when it enters the first of *Aries* ; and their Autumn is between the first of *Aries*, and the first of *Cancer* ; and the Winter between that, and the first of *Libra* ; and between that, and *Capricorn* is their Spring.

THIS may be shown the same way as the former.

THE Seasons in the *Torrid Zone* do not begin in all Places at the same time. 1. Those under the Equator have this peculiar to them, that they have two Summers, two Winters, and as many Springs and Autumns, and that each Year ; so that between the twenty first of *March*, and the twenty first of *September* they have, or should have by the Sun's Course all the four Seasons ; and the same

same again between the twenty first of *September*, and the twenty first of *March*.

ONE Summer is between the first of *Aries*, and the second of *Taurus*, or Tenth of *March*, and Eleventh of *April*.

AUTUMN between the second of *Taurus*, and the first of *Cancer*; or Eleventh of *April*, and Tenth of *June*.

WINTER between the first of *Cancer*, and the twenty eighth of *Leo* or the Tenth of *June*, and Tenth of *August*.

SPRING between the twenty eighth of *Leo*, and first of *Libra*; or Tenth of *August*, and Twelfth of *September*.

AND the same Seasons return when the Sun is in the opposite Places of the *Ecliptic*; which is easily demonstrated on the *Globe*, according to the fore said Definitions, or the Sun's Distance from the *Zenith*. But as to the terrestrial Seasons, they are different in several Places under the *Equator*.

2. THE Places in the North *Torrid Zone* have the end of Autumn, and beginning of Winter at the same time on the twenty first of *December*; but the beginning and end of the other Seasons of Summer and Spring, and also the beginning of Autumn, are not at the same time, but are on different Days in different Places; for the end of Autumn, and beginning of Winter, is there when the Sun is furthest from the *Zenith*, when in the *Meridian*, which happens in the first Degree of *Capricorn*. The other Part is also plain, for if the Places have different Latitudes, the Sun will be in their *Zenith* on different Days; that is, their Summer begins at different Times, and will have a mean Distance from the *Zenith* at different Times, and so their Summer will end, and Autumn begin at different Times. And in the same way, their Winter will end, and Spring begin at different

different times ; because the mean Distance from their Zenith will be different ; tho' it will, in all Places, begin between the Tenth of *December*, and the Tenth of *March*.

3. THE Places in the South *Torrid Zone* have the end of Autumn, and beginning of Winter at the same Time *i. e.* the Tenth of *June* ; but the beginning of Summer and Spring, and the beginning of Autumn, are not at the same Time, but different in different Places ; yet so as the Summer there falls always between the Tenth of *September*, and the Tenth of *December* ; and the end of Autumn, and beginning of Summer, between the Tenth of *March*, and the Tenth of *June* ; and the beginning of Spring, and end of Winter, between the Tenth of *June*, and the Tenth of *September*. This may be proved as the former was ; for the Sun, being in the first of *Cancer*, is then at it's greatest Distance from them ; and then it's Winter in them all ; and the Sun being vertical to them in different times, their Summer, and consequently Autumn and Spring, are at different times.

4. THOSE Places between the Equator and the eighth Degree of North, or South, Latitude have something peculiar ; *viz.* the Sun, by approaching to, and withdrawing from their Zenith, makes two Summers, two Springs, and but one Autumn, and one Winter in a perverted order, thus ; Spring, Summer, Spring, Summer, Autumn, Winter.

THE Cause of this Paradox is this : suppose a Place in the eighth Degree of North Latitude, the Sun is vertical to it in the tenth Degree of *Aries*, and then Summer and Winter will be to them when the Sun is in the first of *Capricorn*, which is twenty seven Degrees thirty Minutes from the Parallel of the eighth Degree of North Latitude ;

Latitude; and the Sun will have a mean Distance when 'tis thirteen Degrees forty five Minutes from them; which happens four times in a Year; 1. when in the third of *Gemini*, then the Spring begins, because the Sun begins then nearly to approach to the Zenith of the Place, where it will be Summer again in the twentieth of *Virgo*; and when it comes to the twenty fifth of *Libra*, 'tis at a mean Distance again, and then begins Autumn; the Sun withdrawing from them; and at the first of *Capricorn* it is Winter; and at five Degrees of *Pisces* 'tis at a mean Distance again, and then begins Spring, for the Sun is approaching to them: and the same happens in Places under the eighth Degree of South Latitude.

BUT if the Place be above eight Degrees Latitude, then it doth not hold good; for the Sun in *Cancer*, or *Capricorn*, is here a less Distance than a Mean: for if in the ninth Degree of North Latitude the greatest Distance will be at the first of *Capricorn*, which is thirty two Degrees of Declination North and South; and the Mean sixteen, which is more than the first of *Cancer*'s Distance, which is but fourteen Degrees thirty Minutes; therefore Summer will then last 'till the Sun be sixteen Degrees from their Zenith, which is not 'till the Sun comes to the twenty fourth Degree of *Libra*, about the Sixth of *October*.

THERE seem to be here some new Difficulties; 1. That it cannot be Summer with them when the Sun is in *Cancer*, *Leo*, *Virgo*, for the Sun is in them both going from and to the Zenith; but that 'tis Summer only in the going from the Zenith. I answer, that Summer consists in it's going back from the Zenith to a mean Distance, which it never does 'till it come to the twenty fourth of *Libra*, when the Summer must end.

2. IN Places under the eighth Degree of Latitude, or in the fourth, as was supposed, the Spring could not begin when the Sun is in the third of *Gemini*, for then 'tis going further from the Zenith; but it goes only one Degree further, and therefore we said it was nearly Spring, and we cannot make a fifth Season for that small Matter.

OTHERS may think we should not put Spring between two Summers, but count it all Summer, while the Sun is at less than a mean Distance from the Zenith. And tho' it go a Degree further, yet that will not cool the Air sensibly, but rather, by it's Continuance, increase it; tho' we shall not dispute that matter, only think the Method laid down is best. But enough, or too much, of this (*a*).

(*a*) Mr. *Ditton* has given a geometrical and easier Demonstration of this Paradox. By the Definitions explained under *Prop. 2.* Each of those Places should be so situated, that two Points may be taken in its Meridian, one lying to the North, the other at an equal Distance to the South; the Distance whereof suppose from the Vertex equal to the mean Distance of the Sun from the same. Let now *AB* be the Equator, (*Fig. 32.*) *CD* and *EF* the Tropics, and *CAE*, *FBD*, the Meridian of the Place, and a Place therein *b*, as remote as possible from the Equator to the North. The North Point therefore is *C*, whose Distance *bC* is equal to the mean Distance of the Sun, or half *bE* (for because there is no least Distance of the Sun, therefore the mean Distance is half the greater) that is, to a third of *CE*, or $\frac{4}{3} = \frac{2}{3} 15$. Therefore as *CA* is $23\frac{1}{2}$, *Ab* will be nearly eight Degrees; and therefore all these Places are nearly within eight Degrees of the Equator. But the Sun proceeding in its annual Motion from *E* to *C*, and then again returning to *E*, produces the abovementioned Seasons in this Order. When in the Point *E*, where the Distance is greatest from the Place *b*, it begins Winter, in *d* the Spring (*viz. bd = bC*) in *b* the Summer, in *C* the second Spring, in *b* the second Summer, and in *d* the Autumn.

P R O-

PROPOSITION IV.

A Place being given in the Torrid Zone, to find the Days when the Summer, Autumn, Spring, and Winter begin and end there.

1. IF the Place be in the Equator, we shewed in the preceding Proposition when the Seasons of the Year begin ; each returning twice in one Year.

2. IF the Place be beyond the eighth Degree of Latitude, bring it to the brass Meridian, and mark with Chalk the Place it is under ; then turning the Globe observe what Part of the Ecliptic comes under the Mark, and when the Sun comes there, Summer begins ; then observe the middle Degree between the Mark, and the Tropic of *Capricorn*, if the Place have a North Latitude, but the Tropic of *Cancer* if South ; and turn the Globe 'till two Points of the Ecliptic come under that middle Degree : the one is the Place the Sun is in when Spring, the other when Autumn begins ; and Winter will be when the Sun is in the first of *Capricorn*, if the Place be to the North, but *Cancer*, if to the South of the Equator. The same may be done by the Maps, but more accurately by the Tables of Declination.

IN which find the Declination equal to the Latitude, and against it you will have four Days of the Year ; and take that Day for the beginning of Summer which is between the Tenth of *March* and *June*, if the Place be North ; and between the Tenth of *September*, and Tenth of *December*, if South Latitude.

THEN take the half of the Latitude from eleven Degrees ninety five Minutes, and find the Remainder in the Table, you will see again four Days against it, in two of which the Sun is at a

mean Distance from the Place ; and if the Place be North, take two Days, one between the Tenth of *December*, and Tenth of *March*, the other between the Tenth of *September*, and Tenth of *December* ; the former will be the beginning of Spring, the latter of Autumn : but if the Place be in South Latitude, take the Day between the Tenth of *June*, and the Tenth of *September*, for the beginning of Spring ; but for Autumn, take that between the Tenth of *March*, and Tenth of *June* ; and Winter will begin the Tenth of *June*, or *December*, as the Place is South or North.

3. IF the Place have less than eight Degrees of Latitude, it will have two Summers, two Springs and Autumn, and Winter, except we reckon the Spring between two Summers to be a Part of a long Summer, and then we do as in the former Case ; but if we reckon there two Summers, and two Springs, according to our Definitions ; find, as before, the beginning of Summer and Winter, and take out of the Table four Days at a mean Distance, and take two of them as before for the beginning of Spring, *viz.* that which is next to the first of Summer ; and for the second Summer's beginning, take the Day that is as far from the twenty first of *June*, as the first Summer's beginning.

PROPOSITION V.

In the Temperate and Frigid Zone the four Seasons are almost of the same Length ; but in the Torrid Zone they are unequal ; yea one and the same will be different in different Places there.

THE

THE former Part of the Proposition is plain, because the Sun goes thro' three Signs in each Season, and so the Times will be nearly equal, excepting a few Days, viz. five that the Summer, and four that the Spring, in northerly Places exceeds the Autumn, and Winter and in Places southerly the Autumn, and Winter exceeds the Summer and Spring as much, because of the Sun's Eccentricity; as we said before.

2. IN Places under the Equator there are two Summers (and likewise the other Seasons) and both short; and the two Springs also, each having only thirty Days, and both Summers and both Springs have sixty four Days, i. e. two Months, and two or four, Days: but the Autumn and Winter have fifty five Days, and the two Autumn one hundred and ten, and the two Winters as many, i. e. near four Months.

3. THE nearer the Places in the *Torrid Zone* are to the Equator, they have the longer Summer, and the less Winter; and an Autumn and Spring more or less ordinary. In Places of less than ten Degrees Latitude, the Summer is no less than six Months; and how long each Season is, may be known by the preceding Proposition.

SO far of the celestial Seasons; but 'tis not from these only that Light, Heat, Cold, &c. do flow; there are other Causes, which we shall now consider.

PROPOSITION VI.

The Sun goes near the Zenith of Places in the Torrid Zone at Mid-day; but at Mid-night goes far from it under the Horizon, and the Places are there almost in the middle of the Earth's Shadow, and the Sun's Rays neither enlighten nor warm their Air.

In the Frigid Zone, as the Sun is a great way from their Zenith even at Mid-day, so at Night it goes but a little way under the Horizon, and sends several Rays by Reflexion into the Air there.

In the Temperate Zone the Sun is at Mid-day at an ordinary Distance from the Zenith, and at Night is a good Way under the Horizon in Winter ; but sends some Rays by Reflexion into the Air in the Summer-time.

TO show this by the Globe : elevate the Pole for the Latitude of a Place in the *Torrid Zone*, or rather put the Poles in the Horizon ; and consider the Parallels which the Sun describes in revolving, how far they are above, and under the Horizon, and the first Part will be plain.

THEN elevate the Pole for the Latitude of a Place in the *Frigid Zone*, and you will see the Parallels are but a little way under the Horizon ; which shows the second Part.

AND again elevate for the Latitude of a Place in the *Temperate Zone*, and you will see the Truth of the Third Part.

PROPOSITION VII.

To find the Continuance of Twilight in a given Place, at a given Time.

IT'S Continuance is from the first appearance of Light to the Sun's rising, and from Sun-setting to it's Disappearance ; which Astronomers have found by Observation to be at eighteen Degrees under the Horizon.

ELEVATE the Pole, to the Latitude of the Place, and find the Sun's Place that Day in the Ecliptic : which being marked, and the Mark brought to the Horizon, and the Index of the Hour Circle to twelve, turn the Globe 'till you find, by a Quadrant of Altitude, or a Pair of Compasses,

Compasses, that the Sun is eighteen Degrees under the Horizon ; and you will see how many Hours the Index hath passed : and so long is the Light in disappearing in the Evening, and in appearing in the Morning ; as may be tried in the East, supposing the Air to be clear, It will be convenient to give an Example in each Zone.

PROPOSITION VIII.

In Places in the Torrid Zone the Twilight is least, and in the Frigid Zone greatest, and in Places in the Temperate Zone, in a Mean between the two.

FOR under the Equator, and in Places near it, the Twilight, according to the former Hypothesis, is about one Hour ; but by Experience 'tis found to be but half an Hour, or a little more ; because the Air, being so gross there, is not so high as is requisite to make Twilight at the Depression of eighteen Degrees ; and besides, the Supposition of eighteen Degrees requires very small Light, such as in the beginning of Twilight : which by the Vulgar is not counted Twilight.

IN the *Frigid Zone* the Twilight lasts for several Days, while the Sun is under their Horizon.

IN the *Temperate Zone* the Twilight lasts three, four, five, or six Hours, and all Night in some Places in Summer-time, according as the Places are more or least near the *Frigid Zone*. These things may be all proved by the Method in the preceding Proposition.

PROPOSITION IX.

A Place being given in the Temperate or Frigid Zone, and another Place in the Torrid Zone, and

likewise the Day of the Year, to find the Hour in the Torrid Zone in which the Sun shall have the same Altitude (and so affect the Horizon with Rays of equal Force) as it hath in the Temperate Zone at Mid-day.

ELEVATE the Globe for the Latitude of the Place in the *Temperate* or *Frigid Zone*, and bring the Sun's Place to the Meridian, and observe it's Altitude, and that is the Altitude of the Rays which warm and enlighten that Place.

THEN elevate the Pole for the Latitude of the Place in the *Torrid Zone*, and applying the Quadrant to the Zenith, mark on it the Altitude before found, and bring the Sun's Place to the Meridian, and the Index of the Hour Circle to twelve, and move the Globe and Quadrant 'till the Sun's Place agree with the marked Degree of Altitude, or the Quadrant, and the Index will show the Hour sought; and therefore the Rays falling in both Places with the same Obliquity, there is the same Degree of Light and Heat in both Places, except other Causes hinder it. *viz.* 1. That the Sun had before introduced a Temper into the Air of the *Torrid Zone*, which it had not into the other Zones. 2. The Sun rising up more directly in the *Torrid Zone*, the Rays are all sent almost the same way; which will cause greater Heat than if it had ascended obliquely, and sent the Rays a great many Ways, which disperses them; whereas Heat requires they should be gathered together.

FOR Example; Let us find out in the equinoctial Day, and Hour when the Sun is as high above the Equator as at *Amstardam* at twelve o' Clock that Day.

PROPO-

PROPOSITION X.

To explain the Causes of Light, Heat, and the Seasons, shewed in the preceding Proposition, under the Torrid Zone.

1. THE Sun rises up directly above the Horizon every day, especially under the Equator, to the Meridian and Zenith of the Place ; and therefore the Rays decline from the Perpendicular at nine in the Forenoon about forty Degrees, and come still nearer to a Perpendicular as they approach to the Meridian, and afterwards decline from it 'till four in the Afternoon, when the Sun begins to send the Rays very obliquely ; and therefore the greatest Heat is between nine and three or four o'Clock, if no other Cause hinder ; and because the Sun in their Meridian hath different Distances from the Zenith, it is Winter when most distant, and Spring at a mean Distance going from the greatest Distance to the Zenith, and Autumn while it goes from the mean Distance to the greatest, either at the first of *Cancer* or *Capricorn*.

2. IN Places under the Equator the Sun is never less than twelve Hours above, and as many below the Horizon ; but in other Places of the *Torrid Zone* 'tis an Hour, or at most an Hour and thirty Minutes more above in the Summer near *Cancer* or *Capricorn* ; and as much in the Winter less than twelve Hours : which causes the Nights to be a little colder, and the Heat of the Day of less continuance in the Winter-time.

3. IN the Night the Sun is far under the Horizon, so that there are scarcely any reflected Rays to enlighten the Air ; which causes the Cold to increase ; and the Air being condensed thereby, to fall

fall down by it's Weight; and their Twilight there is only for about half an Hour.

4. THE same way the Moon rises almost perpendicularly to the Horizon, tho' a little more obliquely, because it goes five Degrees from the Ecliptic, and continues a little above twelve Hours above the Horizon, and almost as many below, going far under the Horizon. And thus it may, by it's perpendicular Rays increase the Heat of the Night, especially if near the Zenith; but the effect is scarce sensible by it's short continuance above the Horizon.

5. ALL the Stars rise and set in Places near the Equator, but in Places near the Pole they do not; and may therefore cause some small Light, and Heat in the Air.

6. IN several Places of the *Torrid Zone*, as in the *Indian Islands*, and *India* itself, and in the South Part of *Africa*, and in *Guinea* in *Africa*, and *Mexico* in *New Spain*, the Earth is sulphureous, and sends forth more hot Exhalations, which give Heat, and some peculiar Properties to the Air. In some Places 'tis sandy, as in the North Part of *Africa*, and in a Part of *Libya*, the *Blacks Country*, and in several Places in *Arabia*, in *Peru*, and Places between *Peru* and *Brazil*; in which Places there is great Heat from the Sand that retains the Heat from the Sun long, and communicates it continually to the Air; in other Places there are several Rivers, but few in these; and in *Abassia*, *Guinea*, *Congo*, *India*, and *Brasil*, there are many Rivers that afford moist Vapours, which beat back the Sun's Heat so as to make it more tolerable.

7. SEVERAL Places in the *Torrid Zone* have the Sea near them, as in *India*, and the *Indian Isles*, and the South Part of *Africa*, *Guinea*, *Brasil*, *Peru*, and the *Mexican Spain*; few Places of the *Torrid Zone* are inland Parts, as the middle of *Africa*, and the

the Countries between *Peru* and *Brasil*, where the Heat and Drought is greater than the former, where the Air is more moist, except other Causes concur to hinder.

8. MOST Countries in the *Torrid Zone* have the Sea almost round them, and in their middle a Chain of Mountains more or less high; as *India*, and the *Indian Isles*, the Tongue-like Part of *Africa*, *Peru*: and this alters the Light, Heat, or causes Rain there; in some Places they keep off the eastern Sun, and in others the western. And the Rains caused there, as in *Chap. 20.* hinder the Light and Heat; and there are but few Places there without those Things, as the Heart of *Africa* and *Mexican Spain*, or may be more.

9. THE Effects of the Winds in the *Torrid Zone* are various and remarkable; for the general Winds blowing to the West cool the Places in the eastern Shores of *Africa* and *Brasil*; but not those on the western, as *Peru*, *Guinea*, *Congo*, *Angola*. Some Winds are peculiar to some Places; as the South Winds in *Peru*, which carry the Vapours before them; other Winds are stated (as in *Chap. 21.*) which change the celestial Seasons, blowing as contrary as the Heavens move.

THE Clouds and anniversary Rains in several Places of the *Torrid Zone* alter the influence of the Sun; being as constant almost as the Sun's Motion: and they are mistaken who think all things in the sublunary World are inconstant, and without Order; and that only the heavenly Bodies are constant in their Motions.

AND seeing those causes are so many and various, some prevailing in one Place, some in another; some at one time, and some at another; either concurring with, or opposing one another, no wonder the Seasons in the *Torrid Zone* should be so changeable.

PROPOSITION XI.

To determine when, or in what Months of the Year, the four Seasons happen on the Earth, viz. Spring, Summer, Autumn, and Winter, in different Places in the Torrid Zone.

WE shewed, *Prop. 2.* that the Seasons in several Places of the *Torrid Zone* do not agree with the Sun's Motion, for 'tis Winter there when the Sun is at, or near, their Zenith; and Summer when it is farthest off: for which reason we distinguish between Seasons that are Celestial, and those that are Terrestrial. We shewed also in *Prop. 3.* and 4. when they had the celestial Seasons in the *Torrid Zone*: and seeing the terrestrial happen not at the same Times, or constantly at one Time, in different Places, we must determine their Times from Experience, and as much as can be shown why they do not agree with the other Seasons in the Heavens; and that from these ten Causes in the first Proposition. And first, we must know that 'tis not a raging Cold, or Frost, that makes Winter in the *Torrid Zone*, but Rains, or less Heat than in Summer; and likewise in several Places of the *Torrid Zone* there are only two Seasons of the Year, Summer and Winter, which are chiefly distinguished by wet and dry; for in Winter there is sometimes more Heat than in Summer, with a difficulty of breathing, for the Clouds and Rain beat down the warm Air; and Spring and Autumn are not so observed and distinguished by Signs.

LET us begin with that Part of *Africa* which is in the *Torrid Zone*, and go round eastward to the *Brasil* thro' the whole *Torrid Zone*.

THE Countries on the western shore of *Africa*, from the Tropic of *Cancer* to *Cape Verd*, which is fourteen Degrees North Latitude, are all fertile

tile in Corn, and several sorts of Apples, and in great Flocks of Cattle, and the Inhabitants of robust Bodies; the Heat there being a little above what is in a Medium; so that they go naked, except their Nobility and rich Men, who cover themselves with Cloaths. The Cause of the Fertility and temperate Air there, tho' it be in the *Torrid Zone*, is, 1. The many Rivers, the chief whereof are *Senega* and *Gambia*, that water the Country, and render the Air the colder. 2. The neighbouring Sea; which affords moist Vapours, and cooling Winds; but how the Seasons are here, and in what Months their Summer and Winter, I have not found among Writers, thro' their Folly or Negligence; tho' I found in a Journal that in one of the Isles not far from *Cape Verd* called *Hesperides*, or *St Vincent*, in Latitude sixteen, the rainy Months, i. e. their Winter are *August*, *September*, *October*, *November*, *December* and *January*, which Time agrees almost with the Season by the Sun's Motion; for in *May*, *June* and *July*, because the Sun is at, or near, their Zenith, it makes their Summer Season, when they have the Air more hot and dry, without Rains; and in *February*, *March* and *April*, it's Spring: for the Sun is then moving from the mean Distance to their Zenith, and they have Heat in a Medium without Rain; and *August*, *September*, *October* make Autumn, because of the Rains then, tho' it should begin sooner, for the Sun is not in *August* come back to a mean Distance; and *November*, *December*, *January* are Winter, the Sun being then furthest from their Zenith; and then they have much Rain, and some Cold; but the Writer says 'tis not so every Year, but for the most part; and does not remember how the Seasons are in the neighbouring Continent of *Africa*; only he adds 'tis quite otherwise on the Shore of *Sierra Leona*, as we shall now show.

2. THEN the South Part of *Africa* that runs East and West, called *Guinea*, that is four or more Degrees of Latitude North. There is continual Heat, without intervening Cold; yet there are some Months they call Summer, others Winter; for on the Shore of *Sierra Leona*, and at ninety Degrees of North Latitude; and in several Places of *Guinea*, they esteem that *March*, *April*, *May*, *June* and *July*, make their Winter, especially *April*, *May* and *June*; for there falls then so much Rain that is hot or warm, and there are such Thunder and Lightning frequently, and such Storms and Hurricanes as cannot be conceived by any but those that have seen them. The *Portuguese* call those Storms *Travados*, which we mentioned in *Chap. 21*. And in these Months the Fields lie waste, without growing Corn; but after the Storms are over, they dig the Ground that is dry, the Rain being drank in, and mix broken Pieces of Coal with it instead of Dung, and let it rot in the Earth for ten Days, then they throw in the Seed; for there is so much Heat in the Air, joined with a Moisture from the adjacent Sea, that if Fish be kept half a Day unboiled after they are taken they stink. In these Places then, their Winter is in *April*, *May* and *June*, when the Rains abound, and the Storms rage; and the Spring in *July*, *August* and *September*; and Summer in *October*, *November* and *December*; and Autumn in *January*, *February* and *March*, when the Rains and Storms begin.

BUT these Seasons are no way agreeable to the Sun's Motion; for there should be a violent Summer there in *May*, *June* and *July*; for the Sun is then at, or near, their Zenith at Mid-day, which the Heat of the Air and Rains testify; and in *October*, *November* and *December*, there should be Winter, for the Sun is then furthest from them. 'Tis not easy to account for those Storms and Lightning they have when the
Sun

Sun is so near their Zenith; it seems to me that the Sun draws up a great Quantity of Vapours from the Sea, and sulphureous Exhalations from the Land of *Guinea*; for 'tis a metalline and sulphureous Earth there, which being condensed by the cold night Air makes Rain; there being no constant Wind blowing to dissipate the Vapours, but a Calmness for the most part before the Storms come; and when these Rains fall the Air is hot, or warm; the Sun being vertical, and the Heat is suffocating; which makes a difficulty in their breathing.

AND tho' their Fields lie waste in the wet Months, yet their Trees and Bushes bear Fruit all the Year round.

THE Day is here almost equal to Night thro' the whole Year; the Sun rising at six and setting at six: but the Sun is seldom seen rising or setting there, for it rises for the most part covered with Clouds for half an Hour; and sets after it hath been involved in the Clouds half an Hour.

'TIS also worth remarking, why in the Months of *July* and *August* the same Rains and Storms prevail not when the Sun is then as near them as in *May* and *June*; and why in the Isles of the *Hesperides*, which are not far from *Sierra Leona* and *Guinea*, the Winter happens in other Months; but here the Summer is from the Sun's Course.

4. HOW the Seasons are in the inland Parts of *Africa* included between an Arch of the Tropic of *Cancer*, and the western Shore of *Africa* and *Guinea*, called the *Blacks* Country, I have not found any thing said of it; but that all things there are almost barren, except those Places near the *Niger*, which overflows each Year in *June*, *July* and *August*, and makes the Land there very fruitful, and forms several Lakes. The other Places on the Confines of *Libya* are oppressed with Heat, being sandy for the most

most part; and the rainy Months do not seem to be here as in *Guinea*.

4. THERE follow the Countries in the Tongue-like Part of *Africa* (which runs North and South) as *Manicongo*, *Angola*, &c. from the second Degree of North Latitude to the Tropic of *Capricorn*; for the Kingdom of *Congo* begins at the second Degree of South Latitude. Their Winter there is like the Spring at *Rome* and *Italy*, being a temperate Heat; they never change their Cloaths, and the very Tops of the Mountains are warm there; the rainy Winter begins almost with our Spring, viz. the twenty fifth of *March*, and lasts during *April*, *May*, *June*, *July* and *August*, to the fifteenth of *September*; and then the Summer begins, which continues 'till the fifteenth of *March*, in which there are scarce any Rains, but a constant Clearness: yet in Winter the Sun is scarce seen in any one Day for the Rain and Clouds. It rains not during the whole Day, but for the most part two Hours before Mid-day, and two Hours after: great Drops fall which are immediately drunk up by the thirsty Grounds. Tho' the Inhabitants make but two Seasons, Summer and Winter, as some do here; yet they may be reckoned four; Summer from the fifteenth of *December* to the fifteenth of *March*; and Spring from the fifteenth of *September* to the fifteenth of *December*; and Autumn from the fifteenth of *June* to the fifteenth of *September*; and the rest Winter, i. e. from the fifteenth of *March* to the fifteenth of *June*.

THE Seasons that are Terrestrial agree nearly with the Sun's Course; for the Sun goes from them, from the fifteenth of *March* to the fifteenth of *September*, and is furthest the fifteenth of *June*; and in the rest of the time it comes to them, and is vertical the thirtieth of *September*; and then goes to a mean Distance southward, and returns from it in *October*, *November*, *December*, *January* and *February*,

ary, and is vertical again the fifteenth of *March*; and in these Months they have Summer by the Sun's nearness; there being no Cause on the Earth to hinder it; and then 'tis Winter from the fifteenth of *March* to the fifteenth of *September*, for then the Sun hath removed from them; but the four Seasons we suppose them to have do not so well agree with the Sun's Course; and I doubt whether they reckon the Spring and Autumn.

BUT the Cause we gave of the rainy Months, viz. that the Sun is then going from them, seems sufficient to produce that effect of itself, therefore we add another; that is, the Chain of Mountains that are to the East from the Sea-Coast; they are still covered with Clouds, occasioned by a stated North-West Wind that blows there at that Time. The Sun draws up the Vapours from the Sea, which that Wind carries against the Mountains; and the general South-East Wind makes also some Resistance to it, and they are thus condensed into Rain; and thence come the constant Rains and Showers, which cause also the overflowing of the *Nile*, and other Rivers in *Africa*; of the natural Cause of which, take the following account.

“ THE River *Nile*, according to best Geogra-
 “ phers rises about fourteen or fifteen Degrees of
 “ North Latitude, which is between the Tropicks,
 “ about nine Degrees to the Southward of the Tro-
 “ pick of *Cancer*, and in its Course to the North-
 “ ward towards the *Mediterranean*, it runs into a-
 “ bout thirty Degrees of North Latitude before it
 “ falls into the *Levant*, and as it is so large a River
 “ and runs thro' the low Grounds of *Egypt*, it can-
 “ not avoid being the Receptacle of a great Conflu-
 “ ence of Rivers, by whom all those heavy Rains
 “ that fall in or near its Passage, or upon the adja-
 “ cent Mountains, are convey'd into its Chanel, and
 “ having no way to disgorge itself till it falls into
 “ the

“ the *Mediterranean*, it is no more difficult to account for its overflowing the low Land of *Egypt* in its Passage thro’ it (tho’ a thing look’d upon by the Antients as supernatural) than it is to account for a Land flood after a sudden heavy Rain in *England*, or elsewhere. This Consideration makes the overflowing of the *Nile* so far from being a wonder, that it would be a much greater wonder and more difficult to be accounted for, if all these excessive and durable Rains that fall into the River *Nile*, and that from the adjacent Country descend into it between or near the Tropics where these Rains fall ; I say it would be a much greater wonder how these heavy Rains and prodigious Quantities of Water could be convey’d to the Sea, and the *Nile* not being affected therewith ; and altho’ the *Nile* seems to be more taken notice of generally than any other River in the World for its annual overflowing, as if it was a Property peculiar to itself only, yet we find *Tonquin*, *Siam*, and other Places within or near the Tropic, that not only have these stated Annual Rains and Overflowings, but depend so much upon them, that they have not moisture sufficient to prepare the Ground for their Rice without them, and if the Rains fail, they have scarce any Crop, and the Poor are miserable for want of Sustenance, as is the Case upon the *Malabar* and *Cormandel* Coasts, as well as at *Tonquin*, the Floods being there generally as certain and constant as in the *Nile*, or any other Place under or within the Tropic, and proceeding from the same Cause.

MOREOVER, the Rivers in *Congo* overflow in these rainy Months, and make great Fruitfulness there, as much, some say in *Egypt* ; and all things grow and ripen excellently.

5. IN the Province of *Lowango*, that borders on the Sea, not far from *Congo*, in Latitude four Degrees, there are also wet Winter Months, and clear

clear Summer Months ; but what is strange, the Months are not the same in which the Rains come in the next Kingdom ; for there are continual and vehement Rains in *Lowango* from the first of *January* to the first of *May*, when yet 'tis Summer in *Congo* in *January* and *February*, and the Sky clear, which is contrary to the celestial Season, for the Sun is not furthest from them in *January* and *February*, and so they should have no Rain, but dry Weather, which must come from some other Mountains, or stated Winds, &c.

6. THE Isles of *St Thomas*, in the Equator, and *Annobon*, in Latitude one Degree thirty Minutes, are most fertile in Sugar, Corn, Apples ; but especially Citrons, and Oranges.

7. HOW the Seasons are on the western Coast of *Africa* from *Lawango* southward I find not.

8. THEREFORE we come round the Cape to the eastern Shore of the Tongue-like Part of *Africa*, where there is *Zofala*, *Mosambique*, *Quiloa*, to the Equator : the Winter there is from the first of *September* to the first of *February*, and Summer the rest of the Year ; whereas in *Congo* the Winter we said was at another Time, tho' both Places have nearly the same Latitude ; but this is owing to the Chain of Mountains that divide that Part of *Africa* into East and West Land.

THE Land in the East Part is not so fertile, but barren and sandy in many Places, and is burnt with Heat sometimes ; tho' the Sea, Rivers, and general Winds, temper the Heat.

9. THE other Countries all the way to the Mouth of the *Arabian* Gulf, and from thence along the Shores of the Gulf to the Tropic of *Cancer*, what Seasons they have we cannot learn ; only that 'tis all barren and sandy, and so must be very hot : (the Sterility and Heat among the *Troglo-dytes*, or *Snake-Eaters*, in *Arabia* is famous) ; and

besides this there are almost no Rivers to water the Country ; but we shall wait for better Accounts.

10. BUT what must the Seasons be among the *Abassines* in the inland Part of *Africa*, where the Equator cuts it almost in the middle ?

11. BUT leaving *Africa* we go to the Countries in *Asia* in the *Torrid Zone* ; where we meet with *Arabia* on the *Red-Sea* from *Mecca* to *Aden*, twelve Degrees North Latitude, having the Mountains of *Arabia* on the East. They have great Heats there in *March* and *April*, and more after that when the Sun goes thro' their Zenith, and keeps near it in *May*, *June*, *July*, and *August* ; the Heat being so great, that they are forced (at least the richer sort) to cause Water to be continually thrown on them in the Day-time, or else they lie in Cisterns filled with Water : the Merchants at *Aden* meet together at Night for Business, and even then they are hot enough. I suppose 'tis for want of watry Vapours from the Earth ; which is stony, and hath few and small Rivers in it. And as for the Vapours from the *Red-Sea*, the general Wind, tho' weak there, yet carries them westward ; there is also a great deal of Sand, which retains the Heat it received in the Day all the Night long ; and communicates it to the Air.

AND this Time of their Winter and Summer agrees with the Sun.

12. THERE is the same Account to be given of all *Arabia*, and it's eastern Shore.

13. IN *Cambaya* and *India*, which is under the Tropic of *Cancer*, and on the *Malabar* Shore in the *East-Indies* towards the West, which reaches to the eighth Degree of North Latitude, the wet Season is from the Tenth of *June*, to the Tenth of *October* ; but chiefly from the middle of *June* to the middle of *September* : nor doth it
rain

rain the same time in all these Places, but more constantly in the Province of *Goa* and *Cochin*, and less in *Cambaya*, where it rains but three Months and seldom at other times : but in *Goa* the Rains tho' not so vehement, begin in *April* and *May*, with Thunder and Storms ; so that we may count Autumn here from the fourth of *March* to the fourth of *June*, and Winter from that to the fourth of *September*, and Spring from that to the fourth of *December*, and Summer from that to the fourth of *March* : for there is a great Drought then, the Water of the former Rain being now drawn out of the Earth. But the Inhabitants count only two Seasons, Summer and Winter, or rather wet and dry, there being no Winter there, according to our Notion of it ; yet 'tis as properly called Winter from the Rains as from Cold.

BESIDES these Rains on the Shore, there are Storms and Thunder in the wet Months, and the Sea is then said to be shut up, and the Rivers then overflow. In the Month of *September* the Sea begins to be open, and the Ships begin to sail from the *Malabar* Shore to all Parts of the World : nor is the Rain severe in the Fields, for they have time to plant and sow for many Hours of the Day (except when there are Storms). For they sow during these rainy Months, which they do not in *Guinea*, as we said ; and the Air is then of a moderate Heat by reason of the Clouds covering the Sun ; so that they take their Diversions in the Fields from the Shore, where there is no Inundation. The Fertility from the Rains is almost incredible ; and if there happen to be no Rains, as in 1630, all their Hope of a Crop is gone ; and there comes a Dearth of Provision, a hot unwholesome Air, Fevers, Pestilence, and Myriads of Men die. In the Year 1630 Man's Flesh was publickly sold in the Stalls of some Towns in *Cambaya*. The Rains are sometimes

so vehement that their Houses, slightly built, fall down, and the Rivers carry others away.

THEY sow in *May* and the beginning of *June*, and reap in *November* and *December*; but 'tis otherwise in *Guinea*.

THEIR Summer and Winter are not according to the Sun's Motion, for in *July* and *August* the Sun is vertical, or nearly so, and thus they should have Dryness and Heat. In this they are very happy, for if the Rains did not fall, and the Clouds continue to cover the Sun, the great Heat of the Sun would make the Land sandy and barren, like *Arabia* and *Libya*, where they have not these Rains when the Sun is vertical; and in *December*, *January* and *February*, they should have Winter, or Rains and less Heat, the Sun being then at the greatest Distance: but they have Summer then; yet the Air is cold enough at Night, and from twelve at Day to twelve at Night there blows a refreshing Gale from the Sea.

14. IN the oriental Shore of *India*, called *Cor-mandel*, the Seasons differ from the Heavens; for the Sun there causes great Heat in *March*, *April*, *May*, and *June*, and no Rains. The *Saracens* divide the Year into three Seasons, hot, wet, and cold. The Heat from the fourth of *May*, to the fourth of *June* is intolerable, the Wind blows from the North, to which if you turn your Face you will feel such Heat in the Air as is perceived near a red hot Furnace; for the Sun is then to the North at Mid-day; and the Stones and Wood are very hot, but the Water in the Wells very cold, so that many are killed by drinking it when they are hot.

THE greatest Heat is between nine in the Forenoon 'till three in the Afternoon, and then there is no travelling; but at other Times 'tis temperate and tolerable, and the Air clear and pleasant, and travelling delightful.

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THE wet Season is from the first of *July* to the first of *November* ; and the Cold from the first of *November* to the first of *March* ; and in *January* and *December* the Cold in the Night is sensible enough.

THERE are here several Things that deserve to be enquired into ; for from the first of *March* to the first of *July* the Sun is nearly vertical to them, and no wonder if the Heat be great then ; yet one would think it should be as hot in *July* and *August*, when the Sun is also over them, and hath the Advantage of the former Heat, and so should be greater : and besides, how come the Seasons there to differ from those on the *Matabar* Shore, being both in the same Climate, and having the Sun vertical and remote at the same times ? And which is more strange, there is only about seventy Miles, and in some Places only twenty Miles Distance between them ; so that you may come from the Places where the Air is clear and hot, to where 'tis rainy, in one Day. *Maffæus* writes thus : ' There are, says he, other things very strange in that Country ; but what especially puzzles Naturalists is, that in the same Months there should be Summer beyond the Mountains of the *Gate*, which run all the way to the Promontory of *Cours*, and on this Side the *Gate* there should be Winter, and constant Rains ; the People, tho' near one another having opposite Seasons.' So far *Maffæus*.

AND this is observed also in other Places, as we have and shall show. It arises from the Situation of the Mountains which divides *Cormandel* and *Malabar*, running North and South, together with the stated Winds ; for on the Shore of *Cormandel* the general Wind is more felt, except in the Summer Months of *May* and *June*, which drives the Vapours against the Mountains, which makes Rain in *Malabar* ; the Mountains are still observed cover-

ed with Clouds in the wet Months, and the Showers more vehement on them, when it rains in *Malabar* : but when it rains in *Cormandel* the Sky is clear on the Mountains, as in *Malabar* ; itself excepting the Months of *July* and *August*, for then it rains in both.

15. IN the Countries on the Coast of the Sea at the Mouth of the *Ganges*, which are opposite to the Shores of *Cormandel*, and are also in the North *Torrid Zone* ; as *Siam*, *Begu*, the Peninsula of *Malacca*, the rainy Months, which cause the Rivers to overflow, are *September*, *October*, and *November* ; but in the Land of *Malacca* it rains every Week of the Year twice or thrice, except in the Months of *January*, *February*, and *March*, in which there is a continual Drought ; this is all against the Sun's Course, whence the Cause must be from the Mountains, or stated Winds, or the adjacent Sea. But because we have not Observations of these Countries accurate enough, we will not insist on them. The overflowing of the Rivers is the chief Cause of the Fertility : and the adjacent Sea, the stated Winds, and the Rivers temper the Heat there, which makes it pleasant living ; there being a plentiful Crop of all kinds of Fruits. In the Kingdom of *Patana*, and near it, the Summer begins with *February*, and lasts to the end of *October* ; in which Time there is a constant Heat, which is moderated with a constant East Wind, and the Air very wholesome. In *November*, *December*, and *January*, there are constant Rains, which yet hinder not a new Crop of Fruits every Month ; and the same may be said of *Cambaya* ; and this Winter agrees with the Sun's Course.

1. LEAVING *Asia*, and sailing thro' the *Pacific Sea*, we come to *America*, which is under the *Torrid Zone*, and it is either North or South ; and the South is either at *Peru* or *Brasil*, which, tho' near,

near, yet have their Seasons at different Times. The Country of *Peru* may be divided into that Part on the Sea, that where the Mountains are, and the Plain beyond the Mountains, which are all in the same Climate. In the mountainous Places they have their rainy Winter from *October* to the end of *March*, when one would think they should have Heat from the Sun's Nearness ; and have Summer from *April* to *October*, in which Time they have no Rain, which they have constantly in Winter ; and so the celestial and terrestrial Seasons differ.

IN that Part of *Peru* next the Sea they have almost no Winter the whole Year, having no Rain ; but they count it Winter from *April* to *October* (which agrees with the Heavens, for then the Sun is gone from them to the Tropic of *Cancer*, and is returning again :) for tho' it doth not rain then, yet the Air is cloudy, and the Sun hid, and it looks as if it were just going to rain, when yet none falls, except a Dew, especially in *June*, *July*, and *August*, every Day before Mid-day : and the dark Weather is not unwholsome, but the Cloud turning to dew it falls down and waters the Vallies. It doth not then rain on the mountainous Places, but the Air is clear. Thus Part of *Peru* on the Shore, is distinguished into Vallies and sandy Places ; the Vallies are most fruitfull, and the sandy Places between the Vallies are barren : and in the adjacent Islands likewise it never rains ; only there falls a great Dew.

YET in the Island of *Gorgon*, which is in three Degrees of South Latitude, it rains for eight Months, with such Thunder and Storms that one would think Heaven and Earth were blended together ; but in *May*, *June*, *July*, and *August*, there is Summer, and a Drought ; against the celestial Season.

IN some Parts here under the *Torrid Zone* there is a considerable Cold ; for in the Province of *Pasoa*, in the Country of *Popay*, in the Valley of *Artisina*, the Seasons both of Summer and Winter are so cold that the Corn does not grow. In the Fields about the Town of *Casco*, near the middle between the Equator and Tropic of *Capricorn* there is no small Frost ; and Snow is found there sometimes.

FROM hence we understand that *Peru* is not very hot, but enjoys rather a moderate Air all the Year, excepting the sandy Ground and hilly Places. The Vallies appear fruitful and pleasant, with their product of Trees and Corn. They have their Water from the Dew that falls, as I said, every Day ; and in Summer from the Torrents that flow down from the mountainous Places ; for there is Winter by the constant Rains : and from these Torrents they let in the Water to their Vallies ; tho' some Vallies are fatiated with the Dew itself, and are very fertile.

THE Cause of this Difference between the Seasons on the Plains and the Mountains of *Peru*, and why it never rains in the Plains, is not so obvious : for they are so near one another, that one may go from the Rain in the Morning to the Plain where there is a clear dry Air. It seems to come, 1. From the Chain of Mountains. 2. From the South-West Wind peculiar to that Place, and which is constantly there. The Wind drives the Vapours against the high Places whereby they are condensed, or else it dissipates them so that they are not condensed on the Plains. We shewed in the Chapter on Mountains how they come to these high Places.

PERU hath this in common with *Egypt*, and some other Places, that the South Winds are not wet and warm, but rather clear up the Air ; which
seems

seems to be in all those Places in South Latitude.

17. THE South Part of *America* call'd *Brasil*, on the East Side between two Degrees of South Latitude to twenty four Degrees, hath so pleasant and wholesome an Air, that no Place excels it, as *Piso* on the Seasons there, in his Book of the *Medicine in Brasil* tells us: it's forepart that is inhabited hath always a pleasant and favourable Gale from the East, which seems to be the general Wind, and not any stated East Wind, that refreshes Man and Beast, keeping them from the intolerable Heat of the Sun that is just above them: and if the Sea flow with it, it comes early in the Morning, but if the Sea flow back from the Shore, 'tis plainly perceived to be later: nor doth it grow weak in the Evening, as in several Places of *India*, but is strengthened with the Sun that moves with it westward, and continues brisk till after Midnight. Nor can the nocturnal Condensations overcome the Dilation and natural Motion of the Air that Way.

ON the West Side of *Brasil*, which separates the vast tract of Mountains from *Peru*, there is a West Wind, which tho' it be unwholesome and late at Night molests them by coming over a vast many unwholesome Bogs, yet it is restrained by the Mountains, and beat back by the morning Gales, that it scarce reaches the eastern Shores.

THOSE pleasant Seasons, tho' they continue without much Alteration, yet there is a Difference in the Night and Day of them; which differ as much, as to heat and cold, as they are equal in length: for when the Sun comes near their Zenith, and hath opened the Pores of the Earth and of their Bodies, it goes far under the Horizon; whence arises a greater Condensation and Coldness in the Air in the latter Part of the Night, when the Dew falls more plentifully; and this rigid Cold continues from three in the Morning, about Cock-crowing,

to the Sun-rising ; and affects their Bodies so as to be hurtful to Strangers : and if they guard not against it, they will have no pleasant Life, either there or on the other Coasts of *India* ; which they in *Brasil* know well ; and therefore have good Fires constantly at their Beds in the Night, against the cold, and venemous Insects.

MOREOVER, the Sun's rising and falling straight up and down makes a short Twilight ; and the Days and Nights to be so equal, as not to be one Hour different.

IN the Summer Nights the Cold is more intense than in the Winter Nights ; which is strange : and it is plainly perceived to be more mild in Winter, when the Air is calm and pressed on all Hands by Clouds, while 'tis gathering the Vapours into Rain.

THE beginning of the wet Season is in *March* or *April*, and is over in *August* ; for the Sun returning from *Cancer* doth turn the Vapours into Wind ; whence arise Storms and Whirlwinds, which the Spring doth soon settle. Those about the Tropics find no change as to the Seasons while the Sun comes to them, and goes from them twice in the Year, as some have thought ; (tho' we have given Examples to the contrary, and even here in *Brasil* ;) but only when the Sun goes from the Equator either South or North.

THERE are only two Times of the Year, one hot and dry, called Summer, the other hot and wet like the *European* Summer, which is their Winter, which is observed in all the *Indies* between the Tropics. The beginning and end of Summer and Winter doth not happen at the same time, because of some Things peculiar to each Place, and the different Distance from the Equator ; yet the Year may be said to contain six Months inclining to a wet, and the other six to a dry Air. And tho' in several Coasts of *Africa* and *Asia*, of the same

same Latitude with us, there arise from thence different degrees of Heat, there is little or none, tho' the Sun goes just over their Zenith in *Brasil* in *October* and *February*, and strikes the Earth with Rays almost perpendicular.

THIS diversity of Heat threatens Death to the Inhabitants by the frequent noxious hot Calms; but here it promiseth constant Health by an over-ruling Gale.

WHENCE we may learn that the Seasons are not so much from the Sun's Motion as from the kinds of Wind, and the different Aspects of the Stars, or Situation of the Place.

SO that in the inland Parts of *Brasil* towards the West, the Nights have been so much colder than nearer the Sea, that the Hair of the Head hath been covered with Hoar-frost in the Morning.

AND there is also in the west of *Brasil* a Summer and Drought, at the same time that there is in the East, Winter Rains, and dark Weather.

YOU may indeed often see the Heavens covered with Clouds brought from the East to the West, but they are thin and much rarified, when the wet Days are not. The Sun when rising or setting may be looked on with steddied Eyes; there is a wonderful clear Sky every where, especially in the Evening, and the Moon that succeeds in the Night finds no Vapours or Clouds in the Air; it being so clear that the old and new Moon may be seen in one and the same Day; and Letters may be read when 'tis but quarter Moon.

THE different Aspect of the Planets, with other concurring Causes, gives a bad Temperature to the Air, which in the Evening flashes frequently with Lightning, even in the clearest and driest Seasons.

THE Drops of Rain are very large, and fall down with great Force; and there is a suffocating Heat that follows, or goes before them.

THE Dew here, especially in Summer, is fatter than that in *Europe*, and more fertile, being more impregnated with Nitte, and more penetrating; being more refined, as appears in it's corroding all Metals, especially Iron; not to mention other Things that are less solid.

THE Meadows and open Fields, tho' less than in Summer, yet, mostly in rainy Months, are delightfully green, however discommoding to the Inhabitants; and tho' they can have no Harvest then, there is Food for their Cattle. So far from *Piso*. And to make the better Judgment we shall mention somewhat from other Authors. All the Fields in *Brasil* rise into little pleasant Hills; there being no high Mountains on the Shores, tho' at some Distance there are seen a few here and there among the dry Hills; and not in every Place, but at the interval of some Miles there are Vallies, watered with little Rivers, which make them fruitful, not in the rainy Months only, but even in Summer. The Hills themselves are by the Heat of the Sun dried up, that not only Grass, but the very Trees sometimes die. It seldom rains all Day, and all Night too; and very seldom for one Day without intermission. The rainy Months are not always the same. In the Year 1643, as *Marcgrave* observed, it rained seven Months, from the first of *February* to the first of *September*, but especially in *May* and *July*; and in 1640 it rained the same time, but especially in *April*, *May*, and *July*; and in 1642 there were six rainy Months, *March*, *April*, *May*, *June*, *July*, and *August*; and it is much alike in other Years. Yet these Observations are only concerning one Place in *Brasil*, viz. *Pernambuca*, in eight Degrees Latitude; but those

those are not the rainy Months in all Places ; nor does the Rain begin and end at the same time in every Place.

IT hence appears, that the Summer and Winter in *Brasil* somewhat agree with the celestial Seasons ; the Rains begin at the Sun's greatest Distance ; and in the mean and least Distance southward there is Heat : tho' there are in some Places some Things that do not so well agree, because of the Winds and Situation of the Places.

18. SO much for South *America*. But North *America* is quite otherwise ; for in *Nicaragua*, a large Province, whose middle is ten Degrees North Latitude, it rains six Months, from the first of *May* to the first of *November* ; in the other Months 'tis hot and dry in the Night as well as the Day, which is against the Sun's Course ; for in *May*, *June*, &c. the Sun is at, or near, the Zenith, and then they should have Heat and Drought, and not Rains ; and in *November* and *December* 'tis more remote, and then there ought to be great Rains.

THE Mountains at *St Martha*, in eleven Degrees North Latitude, are for the most part covered with Snow.

THUS we have considered the Seasons in the *Torrid Zone* ; from which we infer,

1. THAT there is scarcely any Cold to be felt in some Places ; their Winter consisting in rainy Weather. 2. In some Places the Cold is sensible enough. 3. In the Night especially, 'tis cold in the last Watch ; the Sun going so far under the Horizon. 4. One great Reason why the Heat is tolerable, and the Places there habitable, is, that there are no long Days, but all near of the same length with the Nights ; for if they were as long as in the *Temperate* and *Frigid Zone* they could not be inhabited, at least not easily. 5. The Winds much lessen the Sun's Heat. 6. Places have

have Summer and Winter at different Times, tho' in the same Climate, and near one another. 7. The Places that have Heat and Drought against the Sun's Course, are situated in the West, having a Chain of Mountains on their East Side; excepting *Peru*. 8. The Seasons in different Places observe no certain Law. 9. Most Inhabitants in the *Torrid Zone* count two Seasons; as some Writers do, viz. wet and dry; yet there may be counted four, taking in a Spring and Autumn; for as with us the Spring comes near to the Nature of Summer, and Autumn to that of Winter; so may the dry Seasons in the *Torrid Zone* be divided. 10. In some Places there is a continual Autumn, in others only twice in the Year, and in some only in one Part of the Year.

PROPOSITION XII.

To show how the Seasons are in the Temperate Zone.

1. IN this Zone the Cause, first mentioned, in the first Proposition of this Chapter, viz. the Sun's approaching to, or withdrawing from the Place, is so powerful, compared with other Causes, that it doth almost rule the Seasons here of itself. For in the North Countries of the *Temperate Zone*, Spring and Autumn are while the Sun goes from *Aries*, by *Cancer*, to *Libra*, for then 'tis nearer them; then going from *Libra*, by *Capricorn*, to *Aries* again, 'tis Autumn and Winter; but in the South *Temperate Zone* 'tis quite the contrary: nor do other Causes quite take away the Force of this Cause, as they do in the *Torrid Zone*.

LET the Seasons differ in different Places, so as to be more cold or hot, rainy or dry Weather in one Place than in another, tho' both in the same Climate; yet they do not turn Winter to Summer,

Summer, nor Summer to Winter ; for some Land is rocky, some boggy, some near, or far from the Sea ; and some Places sandy, others of Clay.

3. MOST Places near the Tropic are very hot in Summer ; and some have a wet Season almost like that in the *Torrid Zone*. Thus in that Part of *Guzarat*, beyond the Tropic, there are the same wet and dry Months as within the Tropic, and the Summer is changed into wet Weather ; yet there is greater Heat there, as the Sun's nearness requires, than in the dry part of the Year, when there is some Cold ; and we judge not with us of Summer and Winter by dry and wet, but by Heat and Cold.

AND on the Shores of *Persia*, and in *Ormuz*, there is so great Heat in Summer, from the Sun's nearness, that both Men and Women sleep all Night in Cisterns full of Water, and in *Arabia* 'tis as hot.

THRO' almost all *Barbary* (for so the Countries of *Africa* on the *Mediterranean* are called) after the middle of *October* there begins a raw Cold and Rain, as *Leo Africanus* relates ; and in *December* and *January* the Cold is more intense (as 'tis every where in the *Temperate Zone*), but that is only in the Morning ; nor do any then care for a Fire. In *February* the most part of Winter is over, but the Weather is so inconstant as to change five or six times in a Day ; and in *March* the North and West Winds blows very strongly, and fill all the Trees with Blossoms, and in *April* the Fruits are all shaped ; so that in the end of *April*, or beginning of *May* they have Cherries naturally, and in the middle of *May* they gather Figs from the Trees, and ripe Grapes are found in some Places in the middle of *June* ; their Harvest Figs are pulled ripe in *August* : but these and the *Persian Apples* are most plentiful in *September*.

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THE Weather in no part of the Year is so unseasonable as not to have the three Months of Spring always temperate ; they count their terrestrial Spring to begin the fifteenth Day of *February*, and to end the eighteenth of *May* ; in which time they have always a pleasant Gale : if they have no Rain between from the twenty fifth of *April* to the fifth of *May*, they count it a bad Omen ; they count Summer to last 'till the sixteenth of *August*, in which time they have a very hot and clear Air ; they place their Autumn between the seventeenth of *August* and the sixteenth of *November*, and in these two Months their Heat is not so great : yet the Antients counted the Time between the fifteenth of *August* to the fifteenth of *September* to be the Baking Time of the Year, for then the Figs and Quinces, and such kind of Fruit were ripened ; and their Winter they count begins the fifteenth of *November* and lasts 'till the fourteenth of *February* ; and when it begins they begin to till the Plains, but not the Mountains 'till *October*. They are persuaded the Year hath always forty Days very hot, which begin the twelfth of *June*, and as many very cold, which begin the twelfth of *December*. The sixteenth of *March* and of *September* is their Day of Equinox ; and the Day of Solstice is the sixteenth of *June* and *December*. They have great Winds in the end of Autumn, all Winter, and a good part of the Spring ; and are much troubled with Hail, Lightning, and terrible Thunder ; yea and abundance of Snow in many Places, which spoils their Corn, especially when it falls in the day-time, and the Corn is in Flower, as Pease, Beans, &c.

IN the Mountain of *Atlas*, which is thirty Degrees thirty Minutes North Latitude, they divide the Year only into two Parts ; for they have a constant Winter from *October* to *April*, and from *April*

to *October* again is their Summer ; yet there is no Day in which the tops of the Mountains are not covered with Snow.

IN *Numidia* the Seasons of the Year pass away swiftly ; for in *May* they gather their Corn, and in *October* their Dates ; and from the middle of *September* there is a great Cold that lasts until *January*.

WHEN there is no Rain in *October* the Husbandman loses all Hope of sowing his Corn ; and so also if *April* have no Rain. And *Leo Africanus* tells us, there are a great many snowy Mountains not far from the Tropic of *Cancer*.

THE North Part of *China*, tho' in a Latitude not greater than that of *Italy*, extending from thirty Degrees to forty two of Latitude, yet the Cold feels very sharp, says *Trigautius*, for the great Rivers and the Lakes are frozen. The Cause of which is not sufficiently known, except we may say the Cold comes from the snowy Mountains in *Tartary* that are not far off : Which Cold they guard against by the Skins of large Foxes, and *Scythian* Martins, which abound there.

NEW *Albion*, tho' forty two Degrees North Latitude, and as near the Equator as *Italy*, yet is so very cold in *June*, that when *Drake*, the *English* Admiral, went there he was forced to go back to the South Part ; the Mountains being then covered with Snow : the Cause thereof is the cold Constitution of the Ground, being stony.

IN *Egypt*, which is bounded with the Tropic of *Cancer*, the Spring (as *Prosper Alpinus* tells in his Book of the *Egyptian* Medicine) and temperate Time of the Year is in *January* and *February* ; and Summer begins in *March* or *April*, and lasts *June*, *July*, and *August* ; and Autumn is in *September* and *October* ; and the Winter in *November*

vember and *December*. At the beginning of *April* they cut their Corn, and thrash it immediately, and not an Ear is to be seen in the Fields after the twentieth of *May*, nor Fruit on the Trees, and the River begins to overflow the fifteenth of *June*.

IN the Streights of *Magellan*, and the adjacent Countries, tho' they have not a greater Latitude than we have; being fifty two Degrees South; yet their Summer is not very warm, so that the *Dutch* found, in a Bay in the Streights, a large Piece of Ice in *January*, which should be the hottest Month with them; and on the Mountains on the Shore is seen Snow all the Summer: and it is found that in all the Countries of the South *Temperate Zone* the Cold is greater, and the Rains heavier, and in the Summer less Heat than in the North *Temperate Zone*. I doubt whether the Cause of it be that the Sun stays longer in the North Part of the Ecliptic, and moves slower there than in the South Part.

IN the Neighbourhood of the City of *Peru*, in the Province of *Potosi*, there is such a Cold that nothing grows for four Miles round it.

IN the Kingdom of *Chili*, which extends from thirty Degrees of South Latitude to fifty Degrees, the Spring begins in the Month of *August*, sooner than it ought by the Sun's Course, and ends at the middle of *November*; and from that to the middle of *February* there is Summer; and then follows Autumn to the middle of *May*, when the Winter begins, which is very stormy and wet, and carries the Leaves from the Trees, and brings deep Snow, with great Frost; which is soon melted by the Sun if it be not hid behind the Clouds for some Days, which is rare; but there seldom falls Snow on the Vallies; tho' it falls in great Quantity on high Places, and gathers between the Mountains in
Heaps

Heaps as high as the Mountains, and continues there almost all the Year; and when it melts it swells the Rivers, which run violently to the Sea, and overspread the Land, which makes it very fruitful: but tho' it snow seldom in the Vallies, yet it is vehemently cold there, not inferior to that in many Places of *Europe*: partly because of the great Latitude, and partly from a subtle penetrating Wind that comes from the Mountains; which is sometimes insupportable, and makes the Places near the Sea more temperate.

THE Reader may find from Writers other Places different in their Seasons, tho' in the same Climate, or near it. For Example; the Air in *England* is not so cold as in *Holland* or *Germany*: so that the Cattle are not put into Stables in Winter. There is between *Tartary* and *Siberia*, a Place in the *Frigid Zone*, or the North part of the *Temperate*, where are excellent Fields, pleasant Meadows, and scarce any Cold or Winter; where is built the City *Toorn*, which is now increased so as to repel the Insults of the *Tartars*.

IN *Japan*, which extends from thirty one Degrees to thirty nine, North Latitude, there is a cold, snowy, and wet Winter; when other Places in *Europe* of the same Latitude have not such severe Cold, because *Japan* is divided by several Streights, and lies in the middle of the Sea.

IN *America*, and other Places near it, there is great Heat in Summer; for it lies among many little Hills: and the rich go in Summer to the Tops of them, and stay there for some Months; but the poorer Sort only go up in the Day-time, and come back in the Evening.

PROPOSITION XIII.

To show how the Seasons are, and what Day-light they have, in the Frigid Zone.

THE Causes of the Seasons and Day-light, delivered in the beginning of this Chapter, are thus in the *Frigid Zone*.

1. THE Sun's Center doth not rise above the Horizon for some Days, or Months, according to the Sun's Distance from the Pole.

2. WHEN the Sun is above their Horizon it sends it's Rays obliquely to them, while it revolves about the Horizon.

3. THE Sun does not go far under the Horizon, even in Places at, or near, the arctic Pole; and tho' it's Center doth not rise, yet it's Limb appears for some Days before the Center riseth; for the Sun's Semidiameter subtends an Angle of fifteen Minutes. For Example; Take a Place near the arctic Pole, whose Latitude is sixty seven Degrees, and elevate the Globe to that Latitude, and you will see, at the North Part of the Horizon, that no Degree of the Ecliptic, from the nineteenth of *Sigittarius*, to the eleventh of *Capricorn*, or the Sun's Center, at those Degrees will rise for twenty three Days, from the thirtieth of *November* to the Twenty first of *December*; and yet a Part of the Sun will be all that time above the Horizon. On the tenth of *December* the Limb touches the Horizon; thirtieth of *November* and twenty first of *December*, half of the Sun will be above the Horizon, and it's Center in the Horizon; and when it's Center comes to the fourteenth of *Capricorn* it will be all above the Horizon, about the twenty fourth of *December*; and so when

in the sixteenth of *Sagittarius*, or about the twenty sixth of *November*.

BUT in Latitude seventy, or seventy five, the Difference between the rising of the Center and it's Limb will be small, scarcely one Day, or one Day and a half; for the Declination of the Sun doth then begin to increase and decrease very fast.

FROM this small Depression it follows, that they must have the Twilight before Sun-rising, and after Sun-setting, for some Hours; and tho' the Sun rise not for a whole Day, yet they will have the Light all or most Hours of the Day.

THERE is another Cause why the Sun is seen before it be elevated above the Horizon; *viz.* the Refraction of the Rays; of which we treated in *Chap. xix.*

AND not only the Sun appears sooner, but the Twilight comes sooner into the Air than it would do if there were no Refraction. We shall give an Example hereafter.

4. THE Moon when full, or nearly so, continues many Days above the Horizon, when the Sun continues under it; and the longer the nearer the Place is to the Pole: yet it is not so high as to afford any Heat. But when the Sun continues above the Horizon for a whole Revolution, the full Moon is never above it.

5. THEY have almost always the same fixed Stars above the Horizon; but not the same Planets. *Saturn* is above it fifteen Years in Places near the Pole, and fifteen below it; and *Jupiter* six above and six below it; *Mars* one Year; *Mercury* and *Venus* about half a Year, from whence may arise great Difference in the Seasons there.

6. THE Land is rocky or stony in most Places; and but in few Places sulphureous, fat, bituminous, or of Clay: in the former Case, the

Land is something barren, and in the latter moderately fertile.

7. THESE Places are furrounded with Sea. We know little of the inland Parts.

8. SOME Countries in the *Frigid Zone* have pretty high Mountains; and some have none at all, but are stretched out into large Plains.

9. THERE frequently blow cold Winds from the Pole; the East Wind is rare, and the West more rarely found there. In the cold arctic Circle the North Winds rage; but in the antarctic the South Winds.

10. THEY have frequent Clouds and Rain.

FROM hence one may easily judge what Seasons they have; for in Winter, when the Sun doth not rise for some Days it must be dark, cloudy, cold, and frosty, that causes the Places to be uninhabited; but they are not quite without Light then, the Moon being long above the Horizon: and there will be some Twilight from the Sun in most Places, tho' both these Causes may be hindered by Snow, Clouds, and Rain; for when the grosser Clouds are not dissipated by the Sun, they continue near the Horizon, and one cannot see far. There is nothing growing there. What some say of the Land being more fertile, and the Air less cold nearer the Pole, does not seem probable; for neither in *Nova Zembla*, which is but sixteen Degrees from the Pole; nor *Spitzburg*, which is but eight Degrees, is there any such thing; but rather Snow, Rains, and cold Winds in the very middle of Summer: nor doth it avail, that Sailors have found in Latitude eighty two, in *Greenland*, as they suppose, that the Grass was green, and the Cold less than in *Nova Zembla*; and that no other Beasts are found there but the *Rain-Deer*, a Species belonging to these North Countries. These Deer are so
I fattened

fattened in one Month with the Herbs there that their Flesh tastes deliciously.

BUT seeing there are no more Examples of that kind in the *Frigid Zone*, we must not make a general Rule from it; especially seeing a Reason may be given peculiar to that one; the Land being boggy and moorish; and the Herbs not so much Land-herbs as Sea-weeds; which are fattening to the Deer, there being no other Herbs nor any Trees on the Spot. The Land contains a fat sulphureous Substance, which being mixed with Sea Water or River Water, brings forth such fat and oily Herbs; and the like Ground is not found in other Places, but rather the quite contrary.

IN these Places therefore there is little Light, but great Snows, Showers, Cold, and Winds from the Pole; which begin when the Sun enters *Capricorn*; tho' in Autumn, when the Sun is going from the first of *Libra* to the first of *Capricorn*, they rage almost as much: but in Spring the cold Weather is more temperate, yet not without Snow, Rain, and cold Wind from the Pole. The Cold begins to be moderate as the Sun goes from the first of *Aries* to the first of *Cancer*; and in that time, or after, the Sun is above the Horizon for whole Days; when the Heat begins; but 'tis not so great as to melt all the Snow, much less the Ice. Wherefore Seamen tell us, there are Snows and Ice that have lain in that Country for ever. Their Summer is from the Sun's entering the first of *Cancer*, to it's coming to the first of *Libra*; in the former Part of it, the Sun is also whole Days above the Horizon, and thereby increases the Heat a little: so that *June*, *July*, and *August* are more mild; and in some Places the Heat is considerable among the Mountains. But this is often hindered by Rains and Clouds, and cold North Winds,

Winds, and sometimes Snow ; so that no Corn can ripen, except in some Places near the arctic Circle.

THAT the Reader may the better judge of these Things, it will not be amiss to give some Account of what the *Dutch* observed in the *Frigid Zone*, when sailing the Streights of *Waygat's* and *Nova Zembla* : for Students may therein find something to make them better acquainted with the use of the Globes.

JUNE 13. 1594. *New Style*. About six Miles from *Nova Zembla*, when the Sun did not set, they measured it's least Altitude at twelve at Night, and found their Latitude seventy three Degrees twenty five Minutes.

OTHERS observed the same Day, but in Latitude seventy seven Degrees twenty Minutes, a great Quantity of Ice, which seemed to cover the whole Sea, so far as they could see from the top Mast.

ON the twenty first of *August* they could not pass thro' the Streights of *Waygat's* for the great Quantity of Ice that came from the *Tartarean* Sea, and that thro' the whole Summer ; so that they were forced to return without doing any thing.

IN another Voyage they found, on the fifth of *June*, the meridian Altitude in the North one Degree ; from which their Latitude was seventy four Degrees : and the Sea was covered with Ice.

ON the nineteenth of *June* they found, from the Sun's Height, their Latitude eighty Degrees eleven Minutes, about *Greenland* or *Spitzberg*. The *English* surveyed the Shores to Latitude eighty two Degrees ; but found the Sea in the middle of Summer so bound up with Ice, that it seemed to be a part of the Land ; and there was a thick Cloud, or gross Vapour above the Sea, so that they could not see far.

ON the eleventh of *August* 1596, in Latitude seventy six, about *Nova Zembla*, they found Ice
that

that reached to the bottom of the Sea; and on the twenty seventh Day they found their Ship so surrounded with Ice, that they were forced to Winter there, without seeing the Sun.

ON the twenty sixth of *September*, the Cold was so severe that they could scarcely endure it: and the Snows were constant; and the Earth was so bound up with Frost that it could not be dug; nor could they thaw it with Fires.

ON the first of *September* the Sun appeared a little in the South Meridian, above the Horizon; and the full Moon was elevated in the North, and was seen going round above the Horizon.

ON the second of *November* they saw the Sun rise South South-East; tho' it did not rise wholly, but went along in the Horizon to South South-West.

ON the third of *November* they saw the Sun rise South and by East; that is a Part of it, tho' they could see it all from the Top of the main Mast.

ON the fourth of *November*, tho' the Air was calm and clear, yet they could not see any of the Sun; but the Moon was then seen for whole Days, being at the Full; and the Cold was most vehement: and after that, no Fire could warm them, and the Snows and Winds were fierce.

ON the ninth, tenth, and eleventh of *December* the Air was clear; but so cold that our Winter was not to be compared with it; and the Stars were so clear that it was pleasant to see them revolve.

THE Sun did not rise all that time; yet they had some Twilight, in the South especially: for there they have most Twilight at twelve o' Clock; which makes their Day in the Winter.

ON the thirteenth of *January* the Air was clear; and from that time they found a sensible increase
in

in the Twilight, and some diminution of the Cold, and a small Heat at Mid-day.

ON the twenty fourth of *January* the Air was also clear; and then they first saw the Limb of the Sun in the South; and afterwards the whole Sun above the Horizon.

ON the second of *May* a strong Wind removed the Ice from certain Places; in the Sea, they had a small Heat some Days, but mostly cold Winds, Snow, and Showers.

IT is remarkable in these Observations, that the Sun left them the second of *November*, which by Refraction (that makes it appear nineteen Days sooner) should not have been so soon. It seems the Difference in the Atmosphere may cause something of this; for the Sun coming to the Horizon after three Months absence, the Air was there thicker and grosser than it was in the former Year; when the Sun had been long under the Horizon. Yet I doubt whether the Diversity of the Air can cause it to disappear so many Days sooner; and it was otherwise observed by those in 1634, when they wintered at *Spitzberg*: for the Sun did then leave them the ninth of *October*, and after a long absence appeared again the thirteenth of *February* 1634; and these two Days are almost equidistant from the eleventh of *December*. And in the last of the two Observations, they might easily err a few Days; for being in their Bed they did not observe the Sun rise on the tenth, eleventh, and twelfth of *February*: or some Clouds or Rain might hinder their seeing it.



CHAP. XXVII.

Of the Shadows which upright Bodies cast when enlightned by the Sun; and of the Divisions of the Earth that arise therefrom.

SEEING Bodies in different Places of the Earth cast Shadows which are directed to different Points; and that other Varieties are observed therein; Men have admired hereat, as not knowing the Cause. And the Inhabitants of the Earth are thereby divided into three Sorts; which Division is also applied to the Parts of the Earth's Superficies they inhabit; whence some are called *Amphiscii*, others *Heteroscii*, and the rest *Periscii*; which we shall explain a little, tho' it belongs not directly to Geography.

SHADOWS take their Denominations from the Points they are stretched out to, as the *Oriental* Shadows, or *Occidental*, from the Sun's being West or East; but we are to consider those chiefly that are in the Plain of the Meridian, from upright Bodies, the Sun being in the Meridian: and these are either North or South.

THE *Heteroscii* are those that have the Shadow of upright Bodies tending to the North or South, every Day of the Year.

PERISCII are those that have such Shadows going round to all Points in one Day.

AMPHISCII

AMPHISCII are those that have such Shadows tending to the North some Days ; and in other Days to the South. But not to exclude Places in the Tropics, for this last kind we substitute the *Ascii*, who on a certain Day of the Year have no Meridian Shadow ; and these are either 1. *Amphiscii*, that have no Meridian Shadow on two Days of the Year ; or on some Days that Shadow tends to the North, and on other Days to the South : or, 2. They are *Heteroscii*, who on one Day have no Meridian Shadow ; and on the other Days the Shadow is always stretched to North or South.

PROPOSITION I.

The Shadow of upright Bodies tends to a Point opposite to that in which the Sun is.

THOSE that are skilled in Optics and Dialling tell us, that the Shadow, the dark Body, and the luminous Body are all in one Plain ; and the end of the dark Body of the Shadow, and the luminous Body are in one Line ; for the erect Body and it's Shadow with a Line from their two Extremities, constitute a Triangle, the three Sides of which must be in one Plane ; and the Body being upright, the Plane thro' it must be so also ; and thus in a vertical Plane. And because the upright Body is between the Sun and the Shadow, these two must be in opposite Points.

THERE are three Parts in the Shadow ; 1. The dark Part, which is terminated by a Line from the upper Part of the Limb. 2. The central Shadow, intercepted between the Ray from the Center, and that from the upper Limb. And, 3. the *Penumbra* ; between the central Ray, and the Ray from the inferior Limb.

PRO-

PROPOSITION II.

Those that live under the Tropics are Ascii-Heteroscii.

FOR when the Sun is in the Tropic of *Cancer*, or *Capricorn*, upright Bodies have no Shadow ; but when the Sun goes nearer the Equator, the Shadow is projected to the North or South.

PROPOSITION III.

Those that live in the Torrid Zone are Ascii-Amphiscii.

FOR take any Point on the Globe, in that Zone ; and the Sun will be twice in the Year in the Zenith of that Place ; and so there will be no Shadow of upright Bodies. But in other Days the Shadow is projected either to the North, if the Sun be to the South of them ; or to the South, if that be to the North of them.

PROPOSITION IV.

Those in the Temperate Zone are Heteroscii.

FOR the Sun all the Year is still more southerly from those in the North *Temperate Zone*, and more northerly from those in the South *Temperate Zone* ; whence the Shadow must always tend North to the one, and South to the other.

PRO-

PROPOSITION V.

Those in the Frigid Zone are Periscii.

FOR the Sun doth not set to them for some Days, but revolves above the Horizon; so that the Shadow must turn round with it.

PROPOSITION VI.

A Place being given in the Torrid Zone, to find when the Inhabitants there will be Ascii.

FIND when the Sun will be vertical to that Place, and there will be two Days when they will have no Shadow; as in *Prop. iii.*

PROPOSITION VII.

The Day of the Year being given, to find those Places where the People are Ascii, or without Shadows.

FIND the Places that the Sun is vertical to that Day, by *Chap. xxiv. Prop. ix.* and those are the Places.

PROPOSITION VIII.

A Place being given in the Frigid Zone, to find when the People there are Periscii.

FIND when the Sun will not set to them, by *Prop. x. Chap. xxiv.* and those are the Days.

PRO-

PROPOSITION IX.

The Day being given, to find where the People in the Frigid Zone will be Periscii; and that the first Day.

FIND the Places where the Sun begins not to set; and you have the People there.

PROPOSITION X.

Those under the Equator have the Shadow one half of the Year to the North of them, and on the other half to the South of them: and on the two Days of the Equinox they are Ascii, or without Shadow.

THIS needs no Explanation.

PROPOSITION XI.

To place an horizontal Plane so as an upright Style on it have no Shadow some Days; and on other Days project one either to the North or South, as it is with those in any given Place of the Torrid Zone.

SUBTRACT the Latitude of that Place, from the Latitude of your Place (but add if of different kinds), and what Degrees remain, make your upright Style bend so many southward from the Perpendicular; and the Plane to which the Style is perpendicular, bending along with it, will be the Plane on which Shadows will be projected as on the horizontal Plane in that Place of the Frigid Zone.

PROPO-

PROPOSITION XII.

In Places under the Equator the Shadow of an upright Style is in one right Line, all the equinoctial Days, being on the West Side of the Style in the Forenoon, and on the East Side in the Afternoon; but on other Days the Shadow turns in a Semicircle.

IN Places in the *Torrid Zone*, while the Sun is between the Tropic and the Parallel in which the Place lies, the Shadow describes less than a Semicircle; and in Places in the *Temperate Zone*, while the Sun is in the South Part of the Ecliptic, the Shadow describes also a less Space than a Semicircle; but in the North Part a greater Space, and in the Equinoxes the Shadow is carried thro' a Semicircle, excepting in the Equator, and at the Pole.

THESE may all appear by inspection on the Globe; or by describing a Figure.

PROPOSITION XIII.

In Places in the Torrid Zone, while the Sun is between the Parallel of the Place and the Tropic nearest to it, the Shadow then goes back twice, repeating the Directions to the same Points, once in the Forenoon, and once in the Afternoon: and the Sun will then seem to go back.

ELEVATE the Globe to a Latitude less than thirty three Degrees thirty Minutes; and describe the Parallel of that Latitude. I say while the Sun is between that and the Tropic, the Sun and the Shadow will seem to go twice back; and to repeat the same Directions. Apply the Quadrant of Altitude to the Zenith, and turn it about 'till it touch
the

the Parallel, in which the Sun is drawn on the Globe; and bring the Point of Contact to the East of the Horizon. From the Sun in that Point draw a Line to the Zenith of the Place, and it will cut the Line of the Sun's Course in a Point higher above the Horizon, where the Sun will direct the Shadow the same way as when it was rising; having had other Directions repeated between these two. And the same will be on the West Side of the Sun's Course, where it will set in the same Point it was in a few Hours before.

THIS will appear also in *Fig. 32.* Suppose a Place in the *Torrid Zone*, as *L*, in which there is a Style erected; and let *AMF* be the Tropic, or the Sun's Parallel; and let the Sun be rising in *A*: then the Shadow of the Style is projected in the Line *La*; and when the Sun comes to *C* the Shadow will be in the Line *Lc*, and when it comes to *G* it will be again in the Line *La*, and when it comes to the Meridian in *M* the Shadow is directed South in the Line *Lm*, and when it is in *E*, and sets in *F*, it will again have the same Direction.

COROLLARY.

'TIS no Miracle that Shadows go back on Dials, except they go back on a sudden; or if they Point back to the same Hour-Lines, if the Style be not perpendicular, but parallel to the Poles: and tho' it be perpendicular, yet the Line of Shadows doth not show the Hour, except the Plane of the Dial be in the equatorial Plane.

PROPOSITION XIV.

A Plane being given in the Torrid Zone, and one of those Days in which the Sun and Shadow seem to go back; to find the Point in which the Sun then is, and the Hour when it will be.

ELEVATE the Globe for the Latitude, and mark the Sun's Place in the Ecliptic, and draw with Chalk it's Parallel that Day; and applying the Quadrant to the Zenith, turn it about 'till it touch the Parallel, and it will be on that Point.

AND to find the Hour, observe the Point of Contact, bring the Index to 12 on the horary Circle, and bring the Point to the Meridian, and the Index will shew how many Hours the going back begins before or after Noon.

PROPOSITION XV.

The Lengths of the Shadows decrease as the Sun rises above the Horizon; and vice versâ, increase as the Sun goes from East to the South; and again decrease as it goes from South to West.

FOR the Sun, the higher it is, comes nearer to the Zenith of the horizontal Plane; and therefore the Ray that terminates the Shadow comes nearer the Style of the Dial; and the Shadow thus becomes shorter: and the Sun being at the greatest Height on the Meridian, the Shadow must be shortest; and in the Horizon it hath no Altitude; and therefore the Shadow is infinite.

PROPOSITION XVI.

Having the Altitude of the Style and Length of the Shadow, to find the Sun's Altitude; and from thence the Hour; if the Latitude and Day of the Month be known.

THE Length of the Style, the Shadow, and the Ray that terminates the Shadow, make a right angled Triangle; and according to *Prop. xv. Chap. ii.* make this Proportion: As the Length of the Shadow is to the Length of the Style, So is the Radius to the Tangent of the Angle of the Sun's Altitude. Then find the Hour by *Prop. iii. Chap. xxix.*

PROPOSITION XVII.

Having the Semidiameter of the Sun and Earth, to find the Length of the Shadow which the whole Earth casts in the Heavens.

THE Shadow of the Earth is conical, as they that are skilled in Optics demonstrate; and may be easily shewn by a Figure. Therefore we are to find the top of the Cone, (which comes on the Moon when eclipsed) how far it is from the Center of the Earth; thus: As the Difference of the Semidiameter of the Sun and Earth, is to the Sun's Distance from us; So is the Semidiameter of the Earth, to the Length of the Earth's Shadow, or of the Axis of the conical Shadow.

PROPOSITION XVIII.

Having the Distance of the Moon from the Earth, and the Length of the Earth's Shadow; to find how much of the Moon will be dark when she is eclipsed, in the Ecliptic itself.

BY the *Rule of Three*; As the Length of the Shadow is to it's Excess above the Moon's Distance; So is the Semidiameter of the Earth, to the Semidiameter of the conical Shadow, where the Moon enters it.

THEN, As the Distance of the Moon is to this Semidiameter of the Shadow; So is the Radius of the Tangent of the Angle, at the Eye subtended by that Semidiameter: which being doubled, gives the Angle opposite to that Diameter of the Shadow; with which compare the Angle opposite to the apparent Semidiameter of the Moon at the Eclipse; and from thence may be known how much is dark: which if you desire in Digits (as Astronomers use to express the Quantity of the Eclipse, and the apparent Semidiameter of the Moon which seems to be about twelve Inches, or Digits, in Breadth) say, As the Diameter of the Moon is to twelve Digits; so is the apparent Semidiameter of the Shadow to the Digits darkened.

PROPOSITION XIX.

The further a Place is any Day from the Equator, or from the Parallel in which the Sun is, the larger the Shadow is at twelve, and other Hours.

BECAUSE the Sun is further from the Zenith of those Places; therefore the Ray that terminates the

the Shadow, is farther from the Style ; and so the Shadow longer.

PROPOSITION XX.

If there be placed a Style above any Plane, so as to look the same Way as the Axis of the World doth, or be parallel to it ; the Shadow of it will fall on that Line of the Plane which is cut by the meridian Circle in which the Sun then is.

FOR the Shadow of the Axis, or Style, falls in the Plane of the Meridian Circle : because the Sun, the Style, and Shadow, are all in one Plane, as was said in *Prop. i.* but as the Shadow falls also on the Plane that it is raised on, it must fall in the Line of common Section of the Plane and meridian Circle.

PROPOSITION XXI.

To describe an Equinoctial Dial.

LET the Plane either of Wood, Brass, or other Matter, be raised above the horizontal Plane, according to the Complement of the Latitude of the Place.

BUT it is better first to draw the Hour-Lines on the Plane thus : Describe a Circle, which divide into twenty four Parts, and draw Lines from the Center to each Part ; any one of these Lines may be taken for 12 of the Day ; but if the Latitude of the Place be small, there is no need to draw the Hours for Night, when the Sun is under the Horizon : upon the Center erect a perpendicular Style ; this Dial being raised, so that the Plane of it shall be in the Equator, the Sun shines the one half of the Year above, and the other, in Winter,

ter, below ; and therefore the Hour-Lines must be on both Sides.

F O R the fixing of it you must find the Hour of the Day, and cause the Shadow to come on that Hour ; or else you must find a Meridian Line, which the Style is to be raised above.

O N this Dial may be drawn several concentric Circles, which will shew the Sun's Place and Declination : Thus, divide the Style in 100 Parts, which being the Radius of a Circle, take the Complement of the Declination, 5 *Degr.* 10 *Degr.* 15 *Degr.* &c. and with the Tangent of these Degrees describe concentric Circles ; and when the end of the Shadow of the Style comes into one of them, it shows the Declination and the Sun's Place, which may be marked on the Circles.

PROPOSITION XXII.

To describe a Dial on an horizontal Plane.

B Y the Globe. Elevate the Globe to the Latitude of the Place, and bring some remarkable Meridian under the Brass Meridian, and the Index to 12 ; then turn the Globe till the Index point to 1 or 11, and observe how many Degrees on the Horizon the point in which the Meridian cuts the Horizon is from the North ; and so many Degrees must the 11th Hour, or the Hour of one, make with the Meridian : then, the same way, make the Index, by turning the Globe, to point to 2 or 10, and you'll have the Degrees for those Hours, on the wooden Horizon, between the Point where the Meridian cuts the Horizon and the North.

T H E N set the Style from the Center of the Dial above the meridian Hour of 12, and elevate it according to the Latitude of the Place ; or rather

ther make a right angled Triangle, whose acute Angle at the Base shall be equal to the Latitude; which being first made of Paper may be afterwards of Brass or Iron, and set upright in the meridian Line. This may be better done without the Globe; which will be easier apprehended by seeing it done, than many Words.

PROPOSITION XXIII.

To describe a vertical Dial, whose Plane shall be due East or West.

THE Plane of the Dial being thus in the Meridian, draw a Line, elevated according to the Latitude, which will be the Line of 12, to those 90 Degr. East or West from you, as your Plane is directed; but it will be the sixth Hour to you: then cut that Line by another in the middle at right Angles, and on it set the Tangent Degrees found by the Globe, from the first Line both ways, and draw thro' these Points Hour-Lines parallel to the first Line, and the Style being parallel must be as broad as three Hours is distant from the first Line. *Note*, if the Vertical be due South or North, you make the Dial on it as in *Prop. xxii.* only the Style must be raised according to the Complement of the Latitude.

PROPOSITION XXIV.

To find by our Dial the Hour at another Place, tho' ever so remote from us.

IT must be considered, whether the other Place be to the East or West; if to the East, they have 12 before us, if to the West after us. Find by the Globe the difference of Longitude between the

two Places, which turn to Time, allowing 15 *Degr.* for an Hour ; and add or subtract that Time from the Hour with us, as the Place is East or West : their Hour-Lines may be also drawn on your horizontal Dial, as in *Prop.* xxii.

PROPOSITION XXV.

To elevate a Plane above our Horizon, and to draw a Dial on it, in which the Shadow will seem to go back, as in Places of the Torrid Zone.

WE shall chuse here the Elevation of 10 *Degr.* above the Horizon of the Place in the Torrid Zone ; then in our Latitude, 52, the Plane must be raised 42, and the Pole will be 10 *Degr.* above it ; then make a Dial on that Plane for the Latitude 10, by *Prop.* xxii, and put out the ends of the Hour-Lines next the Center, and erect an upright Style, a little from the Center, on the meridian Line, so high as it would reach to the back of a Style that looks to the Pole, and the end of the Shadow of the erect Style will show the Hour, and seem to go back on some Days, as we said above. All other kinds of Dials may be made by the Globe ; but because this belongs to *Gnomonics* we shall not treat further of it.



CHAP. XXVIII.

Of comparing the Celestial Appearances in different Places of the Earth.

FROM the Consideration of the Agreement and Disagreement of the celestial Appearances in different Places, there arise different Denominations of the Inhabitants, tho' they are not of different Sorts; some being *Antæci*, others *Periæci*, and others *Antipodes*.

ANTOECI are those that live in the same Semicircle of the Meridian; but on different Sides of the Equator, and at equal Distances from it.

PERIOECI are in the same Parallel, but in different Semicircles of the Meridian: sometimes all the People in one Parallel are called *Periæci*; but we shall not take it so, to avoid Confusion.

ANTIPODES are those that are diametrically opposite to one another.

NOTE, these three Names do for the most part signify the People in both Places, as we explained them; tho' sometimes they denote only those of one Place, as when we say such People are *antæci* or *antipodes* to others.

PROPOSITION I.

Those that live in the same Semicircle of the same Meridian, have all the same Hours at the same Time.

FOR when the Sun comes into that Meridian, 'tis twelve at Noon, in all the Places in that Meridian; and therefore they must have all other Hours at the same Time; seeing the Sun's going from their Meridian to another Meridian fifteen Degrees from it makes an Hour; which is the twenty fourth Part of the Revolution to them both.

PROPOSITION II.

They that live on different Sides of the Equator, have different Seasons of Summer, Winter, Spring, and Autumn, at the same time.

FOR the Summer begins in a Place according to the Sun's Course, when the Sun is nearest to it's Zenith: and the Winter begins when the Sun is furthest from it: and because the Sun goes from the North Hemisphere to the South: contrariwise, as it leaves the one, it comes nearer to the other; and therefore 'tis Summer in one Place, the same Time that 'tis Winter in the other. The Changes in the Seasons in the Torrid Zone have something peculiar to them, as in Chap. xxvi.

PRO-

PROPOSITION III.

They that are in the North Hemisphere have, as they look to the Equator, the East on the right Hand, and the West on the left, the South before them, and the North behind them; but they that are in the southern Hemisphere, have the Stars rising on their right Hand, and setting on the left, as they turn their Face to the Equator.

THEY that live on the Equator have the East on their right Hand, and the West on the left while they look to the North, but contrariwise if they look to the South.

THEY that are in the North Hemisphere when they look to the Equator, the Sun will seem to rise and set behind them, while 'tis in the northern Signs; but when in the southern Signs, it will appear to rise and set before them: and the contrary will happen if they turn their Faces to the Poles.

SAILORS, and others who understand not these things, wonder at them; when they come to the South Hemisphere: but they appear plain from the Globe.

PROPOSITION IV.

The Celestial Appearances to the Antœci are these.

1. THEY have Mid-day and Mid-night, and all the Hours at the same Time; as in *Prop. 1.* of this Chapter.

2. THEY have contrary Seasons at the same Time; when 'tis Summer with the one, 'tis Winter with the other; and so as to Spring and Autumn.

3. THE

3. THE Days of the one are equal to the Nights of the other; and the Nights of the one to the Days of the other.

4. WHEN the Days of the one increase to the longest, the Days of the other Place decrease to the shortest; for the Days that are opposite to one another in the Calendar, they have them equal; that is, the twentieth of *April* in the one, to the twentieth of *October* in the other.

5. ON the equinoctial Days the Sun rises and sets at the same Time, but on other Days sooner to one than the other; and these two Days the Sun hath the same Altitude in both Places: but each Hour in the Day on other Days, the Altitude differs.

6. WHEN they look towards one another, the Sun and Stars seem to rise and set on different Hands.

7. WHEN the Sun rises and sets before the Face of the one, it doth so behind the other; and contrariwise.

8. THEY have different Poles elevated equally.

9. THE Stars that never set to the one, are never seen by the other; and contrariwise. These are all plain on the Globe.

PROPOSITION V.

The Inhabitants of the Equator have no Antœci, and their Perioeci are the same with their Antipodes.

THIS is plain from the Definitions we gave of them.

PRO-

PROPOSITION VI.

A Place being given on the Globe, to find who are the Antœci, Periœci, and Antipodes to the Inhabitants there.

FIND the Latitude of the Place by bringing it to the Brass Meridian; and their *Antœci* will be in the same Latitude, on the other Side of the Equator.

BRING the Index of the lower Circle to 12, and mark the Point in the Meridian above the Place given; and also mark the Point above the *Antœci* of that Place: then turn the Globe till the Index point to the other twelfth Hour, and you will have the *Periœci* under the first marked Point of the Meridian, and the *Antipodes* under the other.

PROPOSITION VII.

They that live in the same Parallel, have all the Days and Nights of the Year equal; and each Star continues the same Time above their Horizon: and the same Stars never rise to them, and the same never set. The Sun and Stars all rise and set on the same Point, and each Star is at the same Hour equally under or above the Horizon: they have the same Pole equally elevated, and the Stars rise and set on the same Side to both, when they turn their Face to the Pole or the Equator, and have the same Seasons at the same Times, excepting some Things peculiar in some Places.

THESE Things are manifest from the Consideration of the Stars, and the Situation of the Places on the Globe. If you elevate it to the Latitude of one Parallel, the wooden Horizon will be the Horizon

rizon of all the Places in that Parallel ; which will make the Propofition plain.

PROPOSITION VIII.

The Celestial Appearances of the Pericæci are thefe.

1. ALL thofe Particulars agree to them which we mentioned in the preceding Propofition of the Inhabitants of the fame Parallel.

2. THEY have Hours, which tho' nominally the fame, yet are really contrary ; for when 'tis twelve at Day with one, 'tis twelve at Night with the other ; and 'tis two after Mid-night with the one, when 'tis too after Mid-day with the other, &c.

3. ON the Equinoctial Days the Sun fets to one, while 'tis rifing to the other ; and fo Night-time to the one, is Day-time to the other ; but in the Half of the Year, when the Sun goes thro' the Semi-circle of the Ecliptic next to them, that is, in Spring and Summer, it rifes firft to the one, before it rifes to the other ; and therefore they have Day, or the Sun-fhine, for an Hour, or part of an Hour, at the fame Time ; *i. e.* while 'tis fetting in the Weft to the one, 'tis rifing in the Eaft to the other ; but when the Sun is in the other Half of the Ecliptic, *i. e.* in Autumn and Winter, it fets to the one before it rifes to the other : And fo they have no Day but a Part of Night common to both, and the Sun for fome Time under their Horizons ; yet fo as to begin Night with the one, and end it with the other.

4. THEY may both, the fame Way, fee thofe Stars that decline from the Equator to the Pole, elevated to them at the fame time for fome Hours, or Parts of an Hour, *i. e.* before they fet to one, they rife to the other, and contrariwife : and that
the

the longer, the further the Star be from the Equator; but those Stars that decline from the Equator to the Pole under the Horizon, they never see, at the same Time; for they set to the one, before they rise to the other: and therefore for some Hours, or Parts of an Hour, they are seen by neither of them; and the longer Time, the nearer the Star is to the Pole. Those that are always seen by the *Antæci*, are always hid to the *Periæci*.

5. THAT Part of the Earth which one of the *Periæci* hath on the West, the other hath on the East.

PROPOSITION IX.

The Celestial Appearances compared together, with regard to the Antipodes, are these.

1. THE Sun and Stars rise to the one, when they set to the other, all the Year round; for they have the same Horizon.

2. THE Day of the one, is the Night of the other.

3. THE opposite Days in the Year are equal, and also the Nights; so that when the one hath the longest, the other hath the shortest.

4. THEY have contrary Seasons at the same Time; and the same at different Times.

5. THEY have different Poles, equally elevated; they are equally distant from the Equator, but have it on different Points; they are in the same Meridian, but different Semicircles of it.

6. THEY have Hours nominally the same, tho' really contrary; 'tis Mid-day to one, when Mid-night to the other.

7. THOSE Stars that are always above the Horizon of the one, are always under the Horizon of the other; and they that are long above the Horizon

rizon of the one, are a short Time above with the other.

8. THE Sun and Stars seem to rise on the right Hand to the one, and on the left to the other, when they both look to the Horizon; and if the one have the Sun before or behind, for half an Year or more, the other hath it as long.

PROPOSITION X.

The Pericæci of one Place, are the Antipodes of their Antœci.

AND thus the *Antipodes* of one Place are *Periæci* to the *Antæci* of that Place. This needs no Proof.

PROPOSITION XI.

A Place being given on the Globe, to find where the People have Mid-day, and all the Hours at the same Time; and to find where the Hours are contrary to the Hours in that Place.

BRING the Place to the Brass Meridian, and all Places under it count the same Hours; then bring the Index to 12, and turn the Globe till it come to the opposite 12, and the Place under the Brass Meridian will shew where they count contrary Hours to those of the given Place.

PROPOSITION XII.

A Place on the Globe being given, to find the Places where all the Days of the Year are equal to the Nights of the former Place.

BRING

BRING the given Place to the Meridian, and find the Parallel of the *Antæci*; then will all the Places in the Parallel answer the Question.

BUT if the Place be sought, in which the Days are equal to the Nights of a given Place, and all the Hours the same; then the Place of the *Antæci* is the Answer.

AND if all the Hours must be contrary, then the Place of the *Antipodes* is the Answer.

PROPOSITION XIII.

Having a place on the Globe, and the Day of the Year to find the Hours when the Inhabitants of that place, and their Antæci, can see the Sun at once; and the Hours, or Parts of an Hour, that the one will see the Sun sooner than the other.

FIND by *Prop. iv. Chap. xxv.* the Length of the Day there at that Time, what that Length wants of twenty four Hours, are the Hours in a Day with the *Antæci*; for so many Hours they have the Sun above the Horizon at once, as their Day is long: if the Place be in the Equinoctial, they have each twelve Hours Day; if not, the one of the *Antæci* has more than the other: or thus, if the Length of the Day in the Place given be less than twelve Hours, then the *Antæci* will see the Sun for that Time and more, both before and after that Time; but if the Length of the Day be more than twelve Hours there, then you must take the Hours at Night, and so many the *Antæci* will see the Sun at once: and these Hours are near the Meridian in both Places, the Half before, and the other Half after, for they have the Sun in their Meridian at once.

THE difference of Days, or between the Nights and Days, in the same Place being halved, shows the

Hours that the Sun riseth sooner, or sets later than in the other Place.

PROPOSITION XIV.

Having a place on the Globe, and the Day of the Year, to find the Time that the Inhabitants, and their Pericæci, will see the Sun at once; and how long they cannot see it together.

FIND the Length of the Day and Night at that Time in that Place; then the half of their Difference is the Time that the Sun rises sooner to the one, than it doth to the other; and sets to the one, before it rises to the other.



CHAP.



CHAP. XXIX.

Of comparing the Times in one Place with those of another.

PROPOSITION I.

Having the Hour in one given place, to find the Hour of another place given.

THE Place for which the Hour is given being brought to the Brass Meridian, and the Index to 12, turn the Globe till the other Place come under the Brass Meridian; and the Index will point to the Hour in the other Place.

PROPOSITION II.

Having the Hour in any place given, to show all the places on the Globe, in which 'tis then Mid-day or Mid-night, or any Hour you please. The Problem should be proposed and solved of the Earth itself, it being a Property of the Earth, if we were to proceed scientifically; and this we understand of many of the following Problems.

BRING the Place to the Meridian, and the Index to the Hour of the Place; then turn the Globe till the Index points to 12, and you see under the upper Part of the Brass Semicircle, all the Places where 'tis Mid-day, and in the lower Part

where 'tis Mid-night: and for any other Hour turn the Globe till the Index point to it, and you have the Places where 'tis such an Hour under the Brass Meridian.

PROPOSITION III.

Having the Altitude of the Sun, the Day of the Year, and the Latitude of the place, to find the Hour for that Altitude.

ELEVATE the Pole for that Latitude, and find the Sun's Place in the Ecliptic, and bring it to the Meridian; then fixing the Quadrant of Altitude at the Zenith, and the Index at 12, move the Globe and the Quadrant till the Sun's Place come under the Degree of Altitude marked on the Quadrant; and the Index will point to the Hour.

PROPOSITION IV.

Having the Point the Sun is in at any Hour of a given Day, and the Latitude of the place, to find the Hour.

WORK as in the preceding Proposition, and bring the Quadrant to the Point, and the Sun's Place under the Quadrant, and the Index will show the Hour. What Point the Sun is in, is known by the Mariner's Compass.

PROPOSITION V.

To know by the Globe, (when the Sun shines) the Hour in a place whose Latitude is given.

ELEVATE the Globe for the Latitude, and make it's Axis point to the North; then fix a Needle perpendicular in the Sun's Place under the Meridian,

Meridian, the Hand being at 12 ; turn the Globe till the Needle be under the Sun, and makes no Shadow on the Globe ; and the Index will show the Hour.

PROPOSITION VI.

Having the Hour, as we reckon it, to know the Hour from Sun-rising, i. e. the Babylonish Hour, or the Hour at Norimberg.

THE *Babylonians* of old, and the People of *Norimberg* now, count twenty four Hours, from Sun-rising to Sun-rising the next Day. Elevate the Pole for the Latitude, and bring the Sun's Place to the Meridian, and the Index to 12 ; turn the Globe till the Index point to the Hour given, then the Globe being fixed, bring the Index back to it, then turn it from West to East till it come to the Horizon, and count the Hours from it to the Index Eastward ; and these are the Hours sought.

PROPOSITION VII.

Again, having the Babylonish Hour, to find the Hour by our Reckoning, i. e. from twelve at Day, or Night.

ELEVATE the Pole for the Latitude, and bring the Sun's Place to the Horizon on the East, and the Index to it, and turn the Globe till the Index points to the Hour from Sun-rising ; then bring the Index back to 12, and turn the Globe till you bring the Sun's Place under the Meridian, and you'll see how many Hours 'tis past 12 or before 12, by your reckoning.

PROPOSITION VIII.

Having the Hour, as we reckon it, to find how many Hours are past since the Sun set last; that is, the Italian Hour.

THEY now in many places of *Italy*, as of old in *Greece*, begin their Day at Sun-set; which lasts till the next Sun-setting.

TO find their Hour; elevate the Globe for the Latitude, and bring the Sun's Place to the Meridian, and the Index to 12; turn the Globe till it point to the Hour given, then bring the Hand to 12, and turn the Globe to the East till the Sun's Place come to the Horizon, and count the Hours from 12 to the Index.

PROPOSITION IX.

Having the Italian Hour from Sun-setting, to find the Hour, as we reckon it, from Mid-day or Mid-night.

ELEVATE the Globe for the Latitude, and bring the Sun's Place to the Meridian, and the Index to 12; turn the Globe Westward till the Index point to the Hour given, then the Globe being fixed, bring back the Index to 12, then turn the Globe till the Sun's Place come under the Meridian, and count the Hours from 12 to the Index Eastward; and you have the Hours from Mid-day or Night, according to our reckoning.

PROPOSITION X.

Having the Hour, as we reckon it, in a given Day, to find the Jewish Hour, as they and others reckoned.

IT

IT appears from the Discourse of *Christ*, about the hiring of Labourers to the Vineyard, that the *Jews*, and other Nations before Astronomy was cultivated, divided the Day, from Sun-rising to Sun-setting, into twelve Hours, and the Night into as many, which are called Planetary Hours for another Reason; but they are rather to be called unequal Hours: for seeing neither Days nor Nights are equal, but increase the one half of the Year, and decrease the other, except under the Equator; the Hours must be sometimes longer, and sometimes shorter; tho' near the Equator there is no great Alteration, as we shewed *Chap.* xxv. and therefore they that are far from the Equator, as the *Europeans*, never used that Way, but only they in the *Torrid Zone*, or not far from it.

THE Problem then may be proposed more clearly thus: *Having the equal Hour in any Day, to find the unequal Hour, which is the twelfth part of the Time the Sun is above the Horizon; but the equal Hour is the twenty fourth part of the Time the Sun takes in going from the Meridian till it returns to it; which is the Astronomical Day.*

TO solve the Problem: Elevate the Globe for the Latitude, bring the Sun's Place to the East Horizon, and the Index to 12, and turn the Globe 'till the Sun's Place come to the West: Thus you find the Length of that Day. Then find the Hour from Sun-rising or Sun-setting, if the Hour given be after Sun-setting, by *Prop.* vi. and viii. and say, as the Length of the Day (or Night) in Hours is to twelve Hours; so are the Hours from East (or West) to the *Jewish Hour*.

PROPOSITION XI.

Having the Jewish Hour in a given Day, to find the Hour with us; or to reduce the unequal Hour to the equal.

DO as in the last Proposition, and find the equal Hours in the Day; and when the Sun riseth; then say, as twelve is to the *Jewish* Hour given, so is the Length of the Day to a fourth Number; which add to the Hour of Sun-rising, and you'll have the Hour from Mid-night if the Number of these Hours be above twelve; reject twelve, and you have the Hour from Mid-day.

THE *Jewish* Hours, mentioned in *Christ's* Discourse, cannot be accurately reduced to our Hours, the Day of the Year not being added; therefore that third Hour may be our ninth, tenth, or eighth, and the eleventh Hour may be our fifth, sixth, or seventh, according as the Day was in Summer, Winter, or in the Equinox; but the heat of the Day being mentioned, 'tis likely it was about the Summer Solstice.

PROPOSITION XII.

They who sail to the East, till they come back to the place they left, have seen the Sun rise, pass the Meridian, and set once more than the People they first left; and thus are one Day before them; the first of January is the second to them, and our Saturday they count Sunday; and if they sail round twice or thrice, they will count two or three Days more.

And

And they who sail to the West, round the Globe, count one Day less, so that 'tis the thirty first of December with them, when it is the first of January with others; and our Sunday, they count Saturday; and they lose as many Days as they sail Times round that way.

THIS was formerly a great Wonder to Seamen and others: after they had sailed West and came to the *Oriental Islands*, and found they differed from other *Europeans* there by a Day, they accused one another of Negligence or Sleepiness; but the frequency of the Thing hath now taken away the Wonder, and given Mathematicians occasion to explain the Cause of it; which is very plain, if Men will but conceive aright the Motion of the Sun, or of the Meridians on the Earth, and fix on some Beginning of the Day; for it depends on the diurnal Circumvolution of the Sun, (not on it's proper Motion, as some thought) which may begin at any Meridian Circle, and from thence go round till it come back to the same Meridian.

AND because they that sail Eastward go to a Meridian to which the Sun comes sooner than to that they left, they therefore begin to count another Day sooner. For Example; if they sail fifteen Degrees Eastward, they will begin the Day an Hour sooner, and this Anticipation still increases as they go Eastward; and being come to the opposite Meridian, their Day begins twelve Hours sooner; and having gone round, they begin the Day twenty four Hours sooner than in the Place they came to, where it is Mid-day to both when the Sun is in the South.

AND so they that go West will have the Sun later in their Meridian by a whole Hour, if they sail fifteen Degrees to the West, which postpones
the

the Day still an Hour for every fifteen Degrees, which comes to twenty four Hours in sailing round.

COROLLARY I.

IF one sail Eastward and another Westward, both round till they meet, the first will count two Days more than the second; and if they sail twice round he will count four Days more, tho' they live the same Number of Days; and the Days of the East Traveller will be shorter than the Days of the other.

COROLLARY II.

THE same would happen in whatever Place they should meet one another, and from this was the Fact found first, and often afterwards; for when *Ferdinand Magellan* had passed the Straits of *Magellan* and come to *India*, he found a Day's difference in his Account, from the Account the *Europeans* had there, who sailed to the East; and so it was with all others that sailed round.

COROLLARY III.

HENCE it is that they differ in a Day in some Places near one another in the same Meridian, as in the *Philippine Islands*, and *Macao*, a Sea-port in *China*, possessed by the *Portuguese*, and the *Isles* by the *Spaniards* of *Castile*, as they say; for they are under the same Meridian, yet in *Macao* it is *Sunday*, when in the *Philippines* it is but *Saturday*; and while in *Macao* they have *Easter*, and eat *Flesh*, in the *Philippines* it is but *Lent*; and they celebrate not the Feast till the
morrow:

morrow : the Reason is, the *Portuguese* came East to *India*, and from thence to *Macao*; whereas the *Spaniard* sailed West and came from *America* Westward to the *Philippines*; and tho' they met in two Meridians near the same, yet they differ one Day in their reckoning.





C H A P. XXX.

Of the different rising and setting of the Sun, with it's Altitude, and other Appearances, in different Parts of the Earth.

PROPOSITION I.

To place the Globe, so that the Sun shining on it, those Parts may be illuminated which the Sun illuminates any Day ; and that it may at the same Time appear to what People the Sun riseth every Minute, and to whom it is Mid-day ; to whom it sets, and to whom it is Night, and to whom it is vertical ; as likewise the Sun's place in the Ecliptic, the Day of the Year, and the Hour of the Day in that place.

LET the Place, for which the Globe is to be so situated, be mark'd on the Globe, and brought to the Meridian, and the Point on the Meridian above it be marked with Chalk, and on that Point hang the Globe ; and if you would have it fast, you must run an Iron Rod thro' that Point, and the Center to the opposite Point, and have the same well fixed to some Plain below.

THEN place the Globe due North and South by a Meridian Line, or by the Compass : the Globe being thus placed, you may see every Minute the enlightened Part of the Earth, and that which is dark, and the Places in the middle of the illuminated Part have Mid-day then, and those in the eastern

eastern Meridian that bounds the Light and Darkness have the Sun setting, and those in the western the Sun rising.

T O find the Sun's Place in the Ecliptic: Move a small Needle, placed perpendicularly about the middle of the enlightened Part till it have no Shadow, and that Place on the Globe brought to the Meridian, will show the Declination of that Point of the Ecliptic in which the Sun then is; and the Sun's Place will be known according as the time of the Year is, and from thence the Day of the Year; and that Place where the Needle hath no Shadow, hath the Sun vertical to it, and a Parallel thro' that Place will show all the Places that will have it vertical that Day. And to find the Hour of that Place for which the Sun is thus fixed, bring the Place to the Meridian, and the Index to 12, and turn the Globe till the Place, or that for which the Globe is situated, come to the Meridian, and the Index will show the Hour.

BUT because the Globe cannot revolve while it is fixed to the Iron Rod, it will be convenient to fix a Quadrant on a Meridian, so as to turn round the Pole, or an Arc of $113\frac{1}{2}$ Degrees, which being brought to the Needle's Place, will show the declination of the Sun; from which may be found the Sun's Place and Day of the Year: and the Difference between that Arc and the Brass Meridian counted on the Equator, will give the Degrees; which being turned to Hours, fifteen Degrees to an Hour, will give the Hour of the Day before or after twelve, as the Sun is to the East or West Side of the Meridian.

I F there be fixed to the Pole of the Globe such an Arc of Brass as was before said, there may be fixed to it a piece of Brass that hath a perpendicular Style on it, which piece shall slide up and down, according to the Sun's Distance from the Equator: thus
there

there will be no need of a Needle or spherical Gnomon, and it will be less liable to Error.

PROPOSITION II.

The Globe being placed as before, it may be shewn (when the Moon shines) to what People the Moon appears any time it is above our Horizon; and who have the Moon rising, setting, or in their Meridian.

THESE are all plain from the preceding Proposition.

PROPOSITION III.

The further any place is from the Parallel the Sun is in at any Time, the Sun rises the less above their Horizon.

T A K E any Place in the same Meridian where they reckon the same Hours, then describe the Sun's Parallel for any Day, and it will appear that any Point in it will be further distant from that Place which is furthest from the Parallel, (and the same way it is in the Heavens) and so the Altitude will be less.

PROPOSITION IV.

The nearer a place is to the Pole, the Points on the Horizon in which the Sun rises or sets at the Summer and Winter Solstice, are the more remote; and the same may be said of the Moon and other Planets.

T A K E two Places of different Distances, and elevate the Pole for their Latitude, and you'll see where the first of *Cancer* rises, and the first of *Capricorn*, at both these Elevations, from which you see

see that they are more distant in the greatest Latitude or Elevation; and their Distance from the East in rising, or West at setting, which Astronomers call the *Amplitude*, is greatest in the greatest Latitude.

PROPOSITION V.

The Stars situated between the Parallel of a place not in the Equator, and the Pole, are less elevated above the Horizon of the places between that Parallel and the other Pole, than in the places between the Parallel and the nearest Pole.

THIS is easily tried by elevating the Globe for two Places.

PROPOSITION VI.

In places in the Equator the Sun and Stars rise directly up to the Meridian; but in places out of it obliquely.

DRAW a Parallel of the Sun on the Globe, and place the Poles in the Horizon, and you will see any Point in the Parallel rises directly above the Horizon; then elevate the Globe for some other Latitudes, and you will see the Parallel become more oblique to the Horizon, and most at the greatest Latitude.

PROPOSITION VII.

The greater the Latitude of a place is, a Sign in the Ecliptic takes the more time in rising; but they all pass the Meridian in equal times.

ELEVATE the Globe first for one Latitude, and bring the beginning of the Sign to the Ho-
rizon,

rizon, and the Index to 12, and you will see how many Hours pass before the Sign be wholly above the Horizon: and do so for a greater Latitude, and the Proposition will be plain.

PROPOSITION VIII.

The Day being given, to find where the Sun will rise in any given Point.

THIS Problem should be proposed of the Earth itself, as also those that follow, if we were treating scientifically; for it is a Property of the Earth and not of the Globe; yet the Globe representing the Earth, it is sufficient for Practice.

THE Problem is the same with that *Prop. xi. Chap. xxiii.* where having the Point and the Day of the Year in which the Sun riseth, to find the Latitude of the Place, or the Parallel in which we may be sure we are.

PROPOSITION IX.

The Day and Hour, or Part of an Hour, being given, to find the Point on the Globe, to which the Sun is then vertical.

BRING the Sun's Place to the Meridian, and mark the Point above it; then find those Places in whose Meridian the Sun is at that Time, and bring them to the brass Meridian; then the Place under the marked Point is the Place sought.

PROPOSITION X.

The Day and Hour being given, to find those places where the Sun hath a given Altitude under ninety Degrees.

FIND

FIND the Place the Sun is then vertical to, and bring it to the Meridian, and fix the Quadrant of Altitude in the Point above it, and mark the given Altitude on the Quadrant; then turning it about, the Mark will go over all the Places where the Sun hath that Altitude above the Horizon.

PROPOSITION XI.

To find all the Places on the Globe where the Sun is rising, setting, and in the Meridian; and what Places are enlightened, or in the dark, at any Hour of the Day given.

FIND the Place where the Sun is then vertical, and bring it to the Meridian, and elevate the Globe for the Place, then all the Places under the Brass Meridian have Mid-day; and those in the West Horizon have the Sun rising; and those in the East Horizon have it setting; and the Places above the Horizon are enlightened; and those under are in darkness.

NOTE, This is to be understood of the Center of the Sun's rising and setting; for the Sun illuminates something more than the Half of the Earth; as we shall see in the following Proposition.

COROLLARY.

WE may thus see where the Sun rises or sets at our Mid-day, or where 'tis Mid-day when 'tis Night in our Horizon; which is a pleasant Diversion.

PROPOSITION XII.

Having the Semidiameter of the Sun, and of the Earth, and the Distance of the one from the other, to find how much of the Earth is illuminated by the Sun.

(Fig. 33.) LET the little Circle be the Earth, A it's Center, and S the Sun's Center, LB and oc will be the Rays that touch the Globe of the Sun and Earth, and distinguish the enlightened from the dark Part, *i. e.* BDc from BEc. Let the two Rays LB, oc meet in R, and BN be drawn parallel to AS. In the Triangle BNL there is given NL, the excess of SL above AB, and BN equal to AS; and BLN is a right Angle, BL being a Tangent; then find the Angle NBL, As BN is to NL, so is the whole Sine to the Sine of the Angle BNL; and LNB and NBL being equal to a right Angle, and BNL equal to ASL or BAR.

THEREFORE the Arc of the Angle NBL is equal to the Arc BM, the excess of DB above ninety Degrees, and so the Arc DC.

AND if we make the Sun's Semidiameter $5\frac{1}{2}$ of the Earth's, and AS 1168 Semidiameters, MB will be thirteen Months more than the half MEQ.

COROLLARY.

WHEN therefore the Center of the Sun rises to a Place, it's Limb rises to the Inhabitants in a Parallel to the Horizon thirteen Minutes under it; and when the Sun's Center sets, it's Limb is seen 'till it's Center set to those in a Parallel thirteen Minutes from our Horizon.

PROPOSITION XIII.

Having the Height of a Mountain, to find how much sooner the Sun will rise, and how much later it will set, than in the Valley below.

FROM the given Height find, by *Prop. v. Chap. ix.* the Interval, or Arc, from which the Top of the Mountain may be seen; or where the Tangent Line will terminate the Arc: this Tangent Ray is the first that can come from the Sun to the Top of the Mountain.

THIS Point in which the Ray, from the Top touches the Earth, is the Place where the Sun rises when 'tis first seen at the Top; and this Arc shows how much the Sun is under the Horizon of the Valley, when first seen at the Top.

THE Problem then comes to this; having the Depression of the Sun under the Horizon, to find how soon it will come to the Horizon: from which it appears, that it will depend on the Time of the Year. Let the Pole then be raised for the Latitude of the Place, and the Quadrant fixed to the Zenith; then bring the Point opposite to that in which the Sun is at a given time to the western Horizon, and the Index to 12, then observe the Degrees of Depression under the Horizon on the Quadrant, and make that Point come as high above the Horizon, by applying it to the Quadrant, and the Sun will then be so far under the Horizon; then turn the Globe 'till it come to it, and the Index will show the Time. But because the Time is small, 'tis better to do it by Calculation. Supposing then the Height of the Mountain three Quarters of a German Mile, and the Depression about three Degrees, the Latitude of the Place thirty eight Degrees, and the

Sun

Sun in the fifteenth of *Leo*, and that the Sun is seen at the Top thirteen Minutes sooner than below. Hence it will appear how unlikely it is that *Aristotle* says of the Tops of *Caucasus*, and *Pliny* of the Mountain *Casius*, viz. that they are enlightened a third Part of the Night. But how high that supppses the Mountains to be we shall show in the following Proposition.

PROPOSITION XIV.

Having the Time that the Sun is sooner seen on the Top than at the Foot of a Mountain, to find it's Height.

ELEVATE the Globe for the Latitude of the Foot of the Mountain; mark the Point on the Ecliptic opposite to the Sun's Place, and find how much the Sun is depressed for that Time; then from that Arc, as a Distance from which the Top can be seen, find the Height by *Prop. iv. Chap. ix.*

PROPOSITION XV.

Having the Moon's Place in the Zodiac, and it's Latitude, to find the Places it will be vertical to in it's Revolution that Day.

MARK the Moon's Place, taken from an Ephemeris, on the Ecliptic, and apply one end of the Quadrant of Altitude to the Pole of the Ecliptic; and the other to the Mark in the Ecliptic; observe the Moon's Latitude on it, and mark the Moon's Place thus on the Globe with Chalk, describe a Parallel thro' it, and all the Places in the Parallel give the Answer. Understand the same as to the other Planets; having their Latitude and Longitude given.

PROPOSITION XVI.

Having the Moon's Place in the Zodiac, with it's Latitude and Day of the Year, to find when it will rise, set, or be in the Meridian in any Place.

ELEVATE the Globe for the Latitude, and mark the Sun's Place, and also the Moon's, as we shewed in the preceding Proposition; then bring the Sun's Place to the Meridian, and the Index to 12, and turn the Globe 'till the Moon rise, be in the Meridian, and set; and the Index will show the Hour. The same may be done for the other Planets.

PROPOSITION XVII.

To find the Places on the Globe where the Moon will be, rising or setting or in the Meridian, at any Hour, having it's Latitude and Longitude.

MARK on the Globe the Sun and Moon's Place as before, and bring the Sun's Place to the Meridian, and the Index to 12; turn the Globe 'till the Moon's Place come to the Meridian; and mark the Hour on the horary Circle; for thereby you know in what time the Moon will come to the Meridian after the Sun; and then describe the Parallel of the Moon, by bringing it to the brass Meridian. Next bring the Sun's Place to the Meridian, and the Index to 12, and turn the Globe 'till it point to the Hour given; and all the Places under the brass Meridian will have the Moon then in their Meridian. Bring back the Index to 12, and turn the Globe 'till it point to the Hour given; then the Point in the Parallel under the brass Meridian, shews the Place where

'tis then vertical: which Place bring to the Zenith of the Horizon; and those in the East Horizon have the Moon setting, and in the West, rising. The same may be done for the other Planets.

PROPOSITION XVIII.

Having the Day and Hour in which there is to be an Eclipse of the Moon; to shew on the Globe all the Places where it can be seen, and particularly those that will have the Moon in their Meridian, and in their Horizon, either rising or setting.

THIS differs a little from the former; but hath a much easier Solution.

FROM the given Day mark the Sun's Place, and the Point opposite to it is the Moon's Place.

FIND the Place on the Globe where the Sun is then vertical, and find their *Antipodes* by *Prop. vi. Chap. xxviii.* and with them the eclipsed Moon will be vertical. Elevate the Pole for the Latitude of that Place, and bring it to the Zenith, and all the Inhabitants above the Horizon will see the Eclipse; and they under the brass Meridian will see it in the Meridian; and those in the West or East Horizon will see it rising or setting.

BUT whereas an Eclipse lasts some Hours, and there may be considered it's beginning, middle, and end, we here consider only it's middle.

AND the Moon being less than the Earth, it illuminates less than an Hemisphere; and is seen at once by the Inhabitants in the lesser Part, so as 'tis not longer seen by those in the eastern Horizon, tho' at the same Time it hath not yet appeared to those in the western Horizon. And we must conceive a small Circle parallel to the Horizon that terminates the light and dark Part: and
how

how much 'tis less than the Hemisphere we shall show in the next Proposition.

PROPOSITION XIX.

Having the Semidiameter of the Earth and Moon, and their Distance; to find how much of the Earth may be illuminated by the Moon at once.

THIS is done the same way as in *Prop. xi.* Let (*Fig. 33.*) the Center of the Earth be S, and of the Moon A, draw the Tangents LB, OC; these are the last Rays that come on the Earth, and so the Arc OHL denotes the Part that is illuminated, where they can all see the Moon at once, which how much less it is than an Hemisphere, will appear by finding the Angle HSL, or the Arc HL. Draw BN parallel to AS, then BA will be equal to SN, and NL the Difference of the two Semidiameters, and BN being equal to AS, and NLB is a right Angle. Then in the Triangle NBL the Angle NBL may be found thus; As NB to NL, so is the whole Sine to the Sine of the Angle LBN, whose Arc is the Difference of HL and a Quadrant. Suppose then the Diameter of the Moon, to be $\frac{4}{5}$ of the Earth's; and in full Moon, let the Moon's Distance be 64 Semidiameters of the Earth, then NL will be $\frac{1}{5}$; and As 64 is to $\frac{1}{5}$, so is 10000000 to 114583 the Sine of 39 Minutes, and so HL is less than 90 Degrees by 39 Minutes or 89 Degr. 21 Min.

A Place therefore being fixed on the top of the Horizon, the People, to whom the Moon rises and sets, will not be those who are visible in the Horizon itself, but in a Parallel of the Horizon, 39 Minutes distant from it.

PROPOSITION XX.

Having the Declination of a Star, to show on the Globe all the Places where that Star will be vertical in it's Revolution.

MARK it's Declination on the brass Meridian, and under that Mark draw a Parallel, and you have the Places.

PROPOSITION XXI.

Having the right Ascension of a Star, and the Day of the Year, and Hour of the Day; to find the Places where that Star will be in the Meridian at a given Hour.

MARK the right Ascension of the Star on the Equator, and bring the Sun's Place to the Meridian, and see what Degree of the Equator is in the Meridian; then the Distance of the two Points observed being turned to Time, shows the Difference of the Times of the Sun and Stars coming to the Meridian; then find the Places where the Sun is in the Meridian at the given Hour, and the Hand being brought to 12, turn the Globe till the Degrees marked on the Equator come to the Meridian; then all the Places under the brass Meridian will have the Star in their Meridian at that Time.

PROPOSITION XXII.

Having the Declination and right Ascension of a Star, and the Time of the Day given, to find by the Globe, (1) The Place 'tis vertical to. (2) The Places where 'tis above, and where 'tis under the Horizon, and (3) where 'tis in the Meridian, and where it then rises or sets.

FIRST

FIRST, from it's right Ascension, find where the Star is then in the Meridian, and keep those Places under the Meridian, and count the Declination of the Star on the Brass Meridian, and you have the Place it is then vertical to; bring that Place to the Zenith, the Globe being elevated for it's Latitude, and those Places under the brass Meridian will have the Star in the South or North Meridian, and those in the Eastern Horizon will have it setting, and in the western rising.

PROPOSITION XXIII.

To find by the Globe the Places where the Sun, Moon, and Stars will be as long under the Horizon as they are above, with us or any others.

BRING the Place to the Meridian, and find the Antœci of that Place; who will have them as long under the Horizon, as they are above in that Place; as may be easily shewn on the Globe.

PROPOSITION XXIV.

To show the Cause why the Length of the Days increases or decreases faster at the Equinoctial than at the Solstices, when there seems to be no difference; and that in all Places, except under the Equator; and the more the further from the Equator.

FOR Example; Let us take thirty Days before the vernal Equinox (from the twenty first of February to the twenty first of March), and thirty Days after the Winter Solstice (from the twenty first of December to the twenty first of January): I would know why the twenty first of March exceeds the twentieth of February, more than the
twenty

twenty first of *January* doth the twenty first of *December*.

THE Parallel for these four Days being drawn, you will see that of the Equator is further from that in the first of *Pisces* or *Scorpio*, than that thro' *Aquarius* or *Sagittarius*, is from that thro' the first of *Capricorn*; whence 'tis there is not much more of the Parallel thro' the first of *Aquarius* above the Horizon, than of that thro' the first of *Capricorn*; but much more of the Parallel, thro' the first of *Aries*, or of the Equator, is above the Horizon, than of the Parallel thro' the first of *Pisces*. Whence we understand that the Length of that Day is owing to the Declination of the Sun, or of the Points of the Ecliptic. Under the Equator the Days are still equal, tho' the Sun seems at the Solstice to stand or change but a little the meridian Altitude; and it will appear that the inequality of the Days is the more sensible, the further the Place is from the Equator; if you elevate the Globe for those Places, you will see a greater Difference in the Arches of the Parallels above the Horizon.

PROPOSITION XXV.

In Places at the Equator the Sun goes faster from the Zenith than in Places near the Tropics, and within the Torrid Zone.

MARK on the brass Meridian, suppose the fifth Degree of Latitude, and another in eighteen Degrees brought to, and marked on the Meridian; and count five Degrees from it towards the Tropics on the brass Meridian, and set a mark there also; it may be shown that the Sun will sooner increase in the five Degrees of Declination near the Equator, than in those from it: for turning the
Globe

Globe 'till a Point in the Ecliptic comes under eighteen Degrees, and 'till again it comes under thirteen, which is five less, it will cut off a greater Part of the Ecliptic than is between the two Points that come under the fifth Degree, and the beginning of the first; and therefore the Sun goes slower from the Zenith in the second Place, than from the Zenith of the Place in the Equator.





THE
COMPARATIVE PART
OF
Universal Geography.

BOOK III.

*Of the Properties arising upon comparing one
Place with another.*



CHAP. XXXI.

Of the LONGITUDE.

DEFINITIONS.

THE Circle of Longitude of any Place is the Circle that passes through the Place, and both the Poles. It is also called a Meridian Circle, which are one and the same Thing; tho' different in some Respects: for the Meridian hath respect to the Motion of the Stars, and the Circle of Longitude to the Earth's Extension, without regard to the celestial Motions. But the Meridian is

is the more common Name, which we shall therefore use here. They are plainly seen on the Globes, and in the Maps, passing thro' every ten Degrees of the Equator.

2. **T H E** Longitude of a Place is the Distance of it's Meridian, from a certain Meridian (measured on the Equator) which is called the first; and the Longitude of the Earth itself is it's Extension from West to East, conceived on the Equator. The first Meridian is made conspicuous on the Globe and in Maps.

3. **T H E** Distance of one Place from another is the shortest Line between them, on the Earth's Superficies.

4. **A N Y** Point on the Globe, or Map, is said truly to represent some Place on the Earth, if it hath the same Situation and Distance to the other Points on the Maps, that the Place hath to the other Places represented by them.

PROPOSITION I.

There is no Meridian determinated in Nature to be the first, and therefore any one may be taken for the first.

T O understand this aright we must go a little back; for some conceive a Mystery here, where there is none. All Superficies both plain and curve are measured by two Dimensions (as a Line is by one, and a Body by three) as is known from Geometry, and the common Business of Life; of which two, one is Length, and the other Breadth; and the one is conceived perpendicular to the other: and these two are not in themselves different; for that we call Length may be called Breadth, tho' the longest is usually called Length.

IN regular Figures, as equilateral Triangles, Squares, &c. these two Dimensions are the same, but the Earth's Superficies is spherical, and the Length not really different from the Breadth, except in our Conception, for the more distinct understanding of the Thing. And these two Extensions may be conceived on the Earth thus; if we take the Periphery of a Semi-Circle from one Point to it's opposite Point, it will be one Dimension; and if that again be cut in the middle at right Angles by a Circle (as the Length and Breadth is taken in all Superficies) that shall go round, and be the other Dimension for measuring the Earth's Superficies, as if it were extended into a Plane. The first of these being only a Semicircle may be called the Latitude of the Globe; the other being a whole Circle the Longitude of it. Some say they are called Latitude and Longitude because a less Part of the Earth was known to the Antients towards the Poles than eastward or westward.

MORE OVER, on the Globe any Semicircles between the Poles may be taken for the Latitude, and a Circle perpendicular to it, for the Longitude, and so on the Earth; but for the memory sake, it is best to take such Lines as have something peculiar and remarkable, as the Line from Pole to Pole, and the Circle that passes in the middle between them, as the Equator doth.

THUS it appears plain, why the Latitude is measured on the Meridian, and the Longitude on the Equator.

THIS Latitude and Longitude of the Earth is not to be taken for those of a particular Place: for they are only expressed so because they are measured on those of the Earth, and are a Part of them.

AND, properly speaking, a Place or Point, hath neither Latitude nor Longitude: and these two different Senses of the Words ought to be well remembered;

membred ; for the Words frequently occur among Geographical Writers ; as when we speak of the Latitude and Longitude of *Spain*, the Words are taken properly for Length and Breadth ; but when we speak of the Latitude and Longitude of a Place, taken as a Point we mean it's Distance from the Equator, and from the first Meridian ; and in my Judgment it were better not to use the Words Latitude and Longitude, but only Distance from the Equator, and from the first Meridian : but being so long used they cannot be now abolished ; and we shall use them hereafter in this Sense.

MOREOVER, the Latitude of a Place hath, like the Latitude of the whole Earth, remarkable Places for the beginning of the reckoning ; as the Poles and the Equator ; but the Longitude going round the Earth, hath no certain Place, for a beginning : and therefore we may begin at any Point in the Equator, and count the Meridian that passes thro' it the first Meridian, from which the rest are reckoned.

WE shall show why these two Distances from the Equator, and the first Meridian are enquired after, as in *Prop. iii.*

PROPOSITION II.

To determine the first Meridian on the Globe of the Earth, from which we are to begin to reckon the Longitude.

WE said before that we may begin at any Point on the Equator to reckon the Longitude, but 'tis better to fix upon one Place, thro' which a Meridian being drawn, may be counted the first. Geographers have not all agreed on this Place. *Ptolemy* chose to make that the first Meridian which passes
near

near the *Fortunate*, which are Islands about one Degree from it; and reckons from thence to the East thro' *Africa* and *Asia*; chusing to begin at a Place inhabited, and which was then the Bounds and Limits of the known Part of the Earth to the West, and to end at the eastern Shore of *Siam* in *Asia*; but *America* being known not many Ages ago, and long after *Ptolemy's* Time, the first Meridian was removed more to the West. Some made that the first which passes thro' the Isle of *St Nicolas*; which is one of those near *Cape Verd*; and *Hondius* chose the Isle of *St James* to be the first Meridian in his Maps.

OTHERS chose that which passes thro' the Isle *del Corvo* one of the *Azores*, because the Needle was found not to decline from the North there, and in the adjacent Seas, but to lie in the meridian Line; and this beginning *Mercator* chooses.

BUT seeing there are other Places where the Needle points to the North, and it doth not so in every Part of that Meridian; Geographers thought this not a sufficient Reason; some fixing it at the Shore of *Brasil*, that runs out into the Sea.

LATER Geographers, especially the *Dutch* choose to begin at the Mountain *Teneriff*, in the *Fortunate*, or *Canary*, Isles, which is counted the highest on Earth, and is called the Pike of *Teneriff*; and the rather because they thought some remarkable Place should be chosen that might be most known to future Ages; and so *Ptolemy's* first Meridian, tho' long observed, was not laid aside without good Reasons. The *French* since the Year 1634 have taken that which goes thro' the west Part of the Isle of *Ferro*, one of the *Canaries*, which the *French* King, *Lewis* the thirteenth, commanded his Sailors and Geographers to observe.

ASTRONOMERS also have taken diverse Places for the first Meridian; the Followers of *Tycho*

Tycho fix it at *Uranoburg*, an Island in the *Danish* Streights, and calculate the celestial Motions to that Place, and from thence accommodate them to the rest. Others chuse other Places according to the Authors of the Ephemeris they use, who calculate the Ephemeris, and the Planets Places for the Meridian of their own Place. As *Origanus* for *Frankfort*; *Maginus* for *Venice*; *Eickstadius* for *Stetin*; *Lansberg* in his Tables takes *Gæsa* in *Zee-land*, and *Reinboldus* the Royal Mountain of *Prussia*.

BUT to say the Truth, all this Difference hath arisen without any Foundation; so that they are to be blamed who first changed *Ptolemy's* Meridian; for it is no matter where they begin, whether at a Place remarkable, or most to the West or East, provided we may know the Situation and Distance of other Places from it accurately; and that variety of first Meridians hath burthened the reading of Geographical Writers with Confusion and Difficulty. Yet because the Knowledge of the Variation of the Needle from the Meridian is of great Advantage, and that Variation encreases to a certain Meridian, and then decreaseth; it will be useful for finding that Variation, and comparing the Increase and Decrease of it, to chuse that for the first Meridian, in which, or in most Places of it, the Needle hath little or no Variation; if any such is to be found.

AND seeing the *Dutch* now use that which goes over *Teneriff*, and they sail to all Parts of the Earth; it will be convenient to use that with them, for the better understanding the Diaries they publish.

AND Students should know in reading of Authors, that where mention is made of the Longi-

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tude of a Place, or of a certain Meridian, where
the Author begins his first Meridian.

PROPOSITION III.

*Having the Latitude and Longitude of a Place, to
find it on the Globe or Map; and so it's Situa-
tion and Distance from other Places.*

THE Problem for which a Method is sought
with so much Care and Industry, is, to find the
Longitude of the Place in which we are; and be-
fore I come to it, I thought fit to premise the Pro-
blem for which the Longitude is wanted; lest the
Reader should be disgusted for want of knowing
the use whereto it is subservient.

FOR Seamen (as to those that travel by Land
they have not much need of it) having gone far
from Land, and not being sure of the Way they
went, because of several Difficulties, they cannot
trace it out certainly in the Maps, and so cannot
determine the Ship's Place, or the Course they
must steer to their desired Port; which they could
do if they had both their Latitude and Longitude.
Mathematicians have taught them to find the La-
titude at Night by the Stars, and in the Day by the
Sun; as we have shewn before: they that pretend
to do it by the Magnetic Needle, show their want
of Skill. And if they had the Longitude, then
where the Meridian they are in cuts the Parallel
of their Latitude is the Place they are in, on the
Globe or Map. And this Method of the Section
of two Lines is used frequently to find a Point's
Place.

FOR the Solution of the third Problem, count
the Degrees of Latitude from the Equator on the
brass Meridian, and having chalked it, draw the
Parallel; then bring the known Meridian the Place
is

is in (which is distant from the first by the Degrees of Longitude) under the brass Meridian, and where it cuts the Parallel of Latitude is the Place sought: if any Meridian be drawn thro' the Place, the Work is easier.

IN strait lined Maps (such as the Seamen's are) find the Latitude on the Margins on both Sides, and draw a Line thro' them which represents an Arc of the Parallels; then at the Head and Top find the Longitude, and draw a Meridian thro' the Degree of Longitude, the Point of Intersection is the Place. Or shorter thus; Lay a Ruler on the Degrees of Longitude, at the Head and Bottom, and set the Degree of Latitude taken from the Map with a Pair of Compasses along the Side of the Ruler, and you have the Point. And the same Way in curve lined Maps; only we must draw circular Parallels.

THIS is the first remarkable Use of the Longitude in sailing.

THE second use is more necessary; *viz.* the Construction of Globes and Maps thereby; for the Places are by the Latitude and Longitude set down on Globes and Maps: and hence it is they are often made so as not to represent the Situation of the Place truly, for want of the true Longitude.

THE third use is also famous; *viz.* the knowing the Hour in other Places when any celestial Appearance happens; of which in the following Proposition.

THE fourth use is to find the Distance of two Places; having their Latitude and Longitude given.

PROPOSITION IV.

The Sun, Stars, and every Point of the Equator or Parallel removes from the Meridian 'tis in, fifteen Degrees in an Hour, or in a Minute of Time, fifteen Minutes of a Degree; and in four Minutes one Degree.

FOR an Hour is but the twenty fourth Part of time in which they revolve from any Meridian 'till they return to it; and three hundred and fixty Degrees in the Circle divided by twenty four gives fifteen in the Quotient.

THE same will appear on the Globe: bring a Point on the Equator to the Meridian, and the Index to 12, turn the Globe 'till the Index Point to 1 or 2, and you will see fifteen Degrees have passed thro' by the Meridian.

COROLLARY.

IF a Place be fifteen Degrees more easterly than another, it will be eight or nine o'Clock with them by an Hour sooner than in the other Place; if thirty Degrees, two Hours sooner; and so they will have the heavenly Appearances so much sooner than the other: but if more westerly than the other, they will be so long behind the other in their reckoning: or, which is the same thing, if one hath an Appearance in the Heavens, as an Eclipse, an Hour sooner than the other, they will be fifteen Degrees more easterly.

Note. When we add the Sun and Planets with the fixed Stars; as in saying they move fifteen Degrees westerly each Hour; we do not understand it to be exactly so, for tho' it is true of the Stars, yet because the Sun and Planets in the mean time

revolve to the East, they come later to the Meridian, and by degrees they remove from the fixed Stars; but it is so little in a Day, (being in the Sun but ten Seconds, and in the superior Planets less), that they are accounted to move fifteen Degrees in an Hour, as the fixed Stars do.

PROPOSITION V.

Having the Time of an Appearance in the Heavens with us, and with others, to find the Difference of their Longitude from ours.

THIS is easy from what hath been said. You are only to turn the Difference of Time into Degrees; counting fifteen Degrees for an Hour: and if their Hours be less than ours, then they are to the West of us, but if more, to the East.

PROPOSITION VI.

Having again the two Times in which there is any remarkable Appearance in the Heavens; to find the Difference of Longitude by the Globe or Map.

TURN the Difference of Time into Degrees, as before; and bring the one Place to the brass Meridian; and consider whether the other lies to the East or West of you, by their Hours being more or fewer, as before; if to the East, count so many Degrees on the Equator easterly, and turn the Globe so many to the West, and the Meridian under the brass Meridian shows the Longitude of the other Place. This may be done better by the Index of the Hour Circle, as before. And on the Map, apply a Ruler to the Longitude of the one, and count so many Degrees on the Map to the other.

PROPOSITION VII.

To find the Longitude of the Place we are in, or our Distance from any known Meridian that is, or may be, drawn on the Globe.

THIS is the Problem whose Solution Sailors have so long wished for, from Mathematicians; and would render Navigation almost perfect, and liable to very few Errors. This for these two last Ages (in which the *Europeans* have failed with great Labour and Success thro' all Parts of the vast Ocean) hath exercised and distracted the Wits of many; and for the Solution of which the *English, Dutch, and French*, have promised each of them fifty thousand Guilders as a Reward. But none have gained it, tho' many have proposed and tried several Methods; and some have been so fond of their own Inventions as to require the Reward; but their Method being examined, hath being found very deficient, as we shall see hereafter. The *Dutch* and *Germans* express the Problem as we have done; tho' many of them use another Phrase; viz. finding the East and West, which is quite another Thing; so great Liberty do the Vulgar take to express Things their own way, tho' ever so improperly. Thus they show us by the Phrase, that they know not what Seamen mean when they speak of finding the East and West, which is a thing from the present Purpose, and which Seamen know well, whatever Part of the Sea they are in, by the help of their Needle, which Points North and South; and without that they may by knowing the North and South know also the East and West; which are on their right and left Hand as they look to the North. But the Matter is to know how far the Meridian they are in

in is removed from the first Meridian on the Equator. Why then, may some say, have Seamen expressed themselves thus? The Reason is, that the Vulgar conceiving things slightly give the same Names to things that are only like to one another; thus they call *America* the *West-Indies*, because it was found out a little after *India*; so here, because the North and South is known by the Needle, and they desire as easy a Way to find the Longitude which is reckoned from East to West; they take it to be finding the East and West Points.

WE come now to the Solution of the Problem for which several Methods have been thought on. All agree in this, that it cannot be done without some celestial Appearance of the Stars or Planets, which the Latitude itself requires (for as to the Dipping-Needle, that is too doubtful, and subject to Errors). Yet it might be done without the Appearance of the Planets, if we could make a Clock to go true at Sea.

WE have shown in the preceding Proposition, that if we have two Times of a celestial Appearance in two Places, their Difference turned to Degrees and Minutes gives the Difference of Longitude. And seeing in an Ephemeris we have the Time of the Conjunction of the Planets, and of Eclipses, their beginning, middle, and end, determined for a Place whose Longitude is known; if then we could find the Hour in a Place at Sea when these celestial Appearances happen, we should have the Difference of that Meridian, from the Meridian for which the Planets Place, or their Conjunction with the fixed Stars, or Eclipses, were calculated. Nor would it be hard to find the Hour of the Place at Sea, for that is determined from the Altitude of the Stars or the Point they are in: but there is no celestial Appearance which can be observed so accurately as to be useful this way.

BUT there are other Ways by which the Longitude is sought after, without the knowledge of the Hour and regarding the Planets Motions. Yet they require the knowledge of Things which are as much wanted, and so have no place here, tho' we shall explain these ways hereafter. Now the knowledge of the Time cannot be had from celestial Appearances. For Example, *Saturn* moves in the *Ecliptic* scarce five Seconds in an Hour; and tho' they may calculate his Place to an Hour and Minute; yet because he moves so slowly he will appear as in the same Place for some Hours; and therefore we cannot compare the Hours in the two Places together; if there be only an Hour, or fifteen Degrees difference in the two Meridians: for in that short time he scarcely alters his Place.

AND so the Sun moves each Hour in the *Ecliptic* about two Minutes and a half; which is too slow for an Observation, tho' very accurate; and an Error of an Hour is easily committed; whereas the Sun must appear in different Places every Minute or two: for if it appear in the same Place for two Minutes, we cannot know exactly the Hour; and an Error of two Minutes will be an Error of half a Degree on the Map, which is seven *German* Miles and a half. The best Appearances (to come within a Minute or two) are;
 1. An Eclipse of the Moon. 2. The Moon's Place in the *Zodiac*. 3. It's Distance from, or Appulse to the fixed Stars. 4. The Moon's entering into the *Ecliptic*, and cutting it. 5. The Conjunction, Distances, and Eclipses of the Satellites of *Jupiter*, which have been wonderfully discovered in this Age, by the help of Telescopes; and greatly confirm the *Copernican* Hypothesis.

The first Method of finding the Longitude; by the Eclipse of the Moon.

THIS is an excellent Method, and accurate enough if there were Eclipses every Night: thus as soon as you perceive, by means of the Telescope, the beginning or end of an Eclipse of the Moon observe the Altitude of a Star, or Point in which it is; which with the Altitude before given, or then found, will give the Hour of the Night. And if the Star be in the Meridian, the Work will be the shorter. And this Hour and Minute compared with that Hour and Minute in which the Appearance is to be, by Calculation, gives the Difference of Time, and so of the Meridians, for which the Calculation was made, and where the Eclipse was seen: or, the Meridian of the Ephemeris being found in the Map, you may find the Meridian you are in, which is either to the East, if the Hours are more, or to the West if less than those in the Ephemeris.

The second Method of finding the Longitude; by the Moon's place in the Zodiac.

THO' that Method by the Eclipse of the Moon is very accurate; yet because those Eclipses are but seldom, nor all seen in all Places, the Problem is not sufficiently solved; and the Seamen will not be much the better for it; yet it is a very useful way at Land, where Mathematicians live, and can observe them truly; for thereby the Longitudes of most Places are set down in the Maps. But this second Method, by the Moon's Place in the Zodiac, may be tried frequently, tho' the Observations and Calculation are very troublesome and perplexed, because of the double Parallaxes; and an Error

ror of an Hour itself may creep into the Work, which will cause a Mistake of about an hundred Miles. Tho' the Error will be less if you take the Minute when the Moon is in the Ecliptic, and find the Hour of the Night, by the Altitude of some remarkable Star, or by the Time it comes to the Meridian, which is better. Then from that Hour find what Point of the Zodiac or Ecliptic is in the Mid-heaven, as Astronomers speak, or in the Meridian, as we shall show, which compare with the Time when the Moon comes to the Meridian, by the Ephemeris; and thus we shall have the Hours in two Places as before, from which the Difference of the Meridians is found.

The third Method; by the Distance of the Moon from some fixed Star.

BECAUSE we cannot observe the Moon in the Meridian for some Nights before and after New Moon, it being near the Sun; and so the use of it is not so frequent as Seamen desire; therefore another Method, which may be more frequently used, is proposed by the appearing or removing of the Moon to or from the fixed Stars; but the Calculation is so troublesome by the Parallaxes, and the Solution of oblique spherical Triangles, that Seamen cannot use it: nor will I trouble young Students with the multitude of Precepts thereto belonging; it requiring Men well versed in Calculations to go thro' it. There is a Monk in *France* called *Duillerius*, who thinks the Difficulties here may be avoided, or easily overcome, by a peculiar Method of his own; having lately published a little Book, in which he professes to give an useful Method to Seamen for discovering the Longitude; adding several other things, and dedicating the same to the *French* King; and afterwards (because per-

haps

haps he got nothing for it) to the Confederate States of *Holland*; and at this Time that I am writing he demands the Reward. In the Book he gives two Rules, tho' they are almost the same; only the first is proposed more obscurely, and is of no service to Seamen. But he contradicts *Euclid's Elements*, yet pretends, that the Error will cause no Error in Practice; and therefore in the end of the Book he adds an easier Method, by which there must be a celestial Globe exactly made, in which the Ecliptic and it's Poles are accurately placed. 2. There must be an Ephemeris for the Sun and Moon, perfectly true, at hand. The Author says he used the *Rudolphin* Tables, and found them to agree with the Heavens. 3. From these Tables must be taken the Latitude and Longitude of the Moon, for that Day in which the Observation is to be made; then applying the brass Quadrant, one end to the Pole of the Ecliptic, the other to the Moon's Place in the Ecliptic, observe the Latitude of the Moon upon it, and mark it; that Mark shows the Moon's Place on the Globe, and it's Situation for that Day: and so from the Tables find the Moon's Place for the next Day, and mark it; then take a narrow Piece of Paper, of a small Length, and apply it to the Globe above those two Marks (for in this the whole Art consists, as he confesses) and marking the two Points on the Paper, and, applying a Ruler, draw a Line from the one to the other; and that Line will show the Moon's way in a Day. Then observe the Moon's Distance from a known Star at that Time, and taking it in Degrees and Minutes from the Equator or Ecliptic on the Globe, fix one Point of the Compass on the Star, and with the other describe an Arch on the Moon's Path, and mark where it cuts it, and bring the Quadrant to it, and you have the Moon's Place in the Ecliptic

Ecliptic at the Time of Observation. Then find by the Ephemeris when the Moon will come to that Point; which being compared with the Time of Observation, gives the Difference of Time, and so of the Longitude. I omit here some Precepts for the Equation of the Time, &c. Thus the Author thinks to be free of the Parallaxes and Difficulties of the Refraction. There seems to me to be several Faults in this Method; but my Book going to the Press, I had not Time to examine all his Rules.

The fourth Method; by the Moon's entering the Ecliptic.

THE Moon's Path cuts the Ecliptic, in two Points, into which when it comes, 'tis said to be in the Ecliptic, and from which it goes five Degrees. There must therefore be observed at Sea, the Time when the Moon comes into the Ecliptic; the Time may be also had when it comes to it by the Ephemeris; and the Difference of the two Times gives the Longitude: but this Method is not easily followed, and the Calculation is very intricate, and subject to Errors; and so can be of little use in the Matter.

The fifth Method; by the Satellites of Jupiter.

MOST Astronomers think this Method preferable to that by the Moon, as not being subject to the Difficulties of the Parallax; and when *Jupiter* is above the Horizon it may still be used. There are four *Satellites* which move about *Jupiter* as their Centre, which may be seen by a Telescope: this was the great Discovery of *Galileo*. Their proper Motion about *Jupiter* is swift; for they have a Motion in common with *Jupiter* about the Sun, and with the other Stars round the Earth; that next *Jupiter* goes round

round in one Day eighteen Hours and an half; the second in three Days thirteen Hours and an half; the third in seven Days two Hours; the fourth in sixteen Days eighteen Hours. Their Motion is to be calculated for every Hour; and their Motions may be found in some Books, tho' not common; and the Time of their Conjunctions with *Jupiter* (or of their immersion or emerfion from his Shadow) being observed with a good Telescope, and the Time of Night when it happens; and consulting the Tables, you will find when that immersion or emerfion is to be; and the Difference of the Time, gives, the Difference of the Longitude.

The sixth Method; by Clock-work.

BECAUSE all the former Methods have this Disadvantage, that they cannot be observed every Night (as is known of the Moon, and so of *Jupiter* when near the Sun); nor is it easy to make Observations of them at Sea, because of the Ship's Motion; therefore some have quitted these, and are now wholly bent upon making a Piece of Clock-work that shall go true with the Sun; and divide the Day exactly into twenty four Parts.

IF such a Thing could be made, it would render the Business easier for Seamen; who then need only to observe truly the Hour of the Place when they left it, and set their Clock to that Hour, which would still show the Hour of that Place wheresoever they went, and finding of the Hour of the Place they are in, as shall be shown; they have, as before, the two Times, which will give the Longitude of the Place they are in.

BUT tho' Artificers have been at great Pains to make such a Piece of Clock-work, yet none have had the good Luck to accomplish it; for both the Matter out of which it is made, and the Air at Sea hinders the equality of their Motions; it moving
faster

faster in hot than in a cold Air. So that the Clock which the *Dutch*, wintering in *Nova Zembla*, had placed in the Houses, ceased to move; tho' they added a greater Weight. To supply this Defect some advise to bring the Clock every Day to the Hour of the Place they come at, which may be observed from the Heavens; yet a great Error will thus creep into the Work; for on the second Day the Longitude of the Places comes to be found this way, there will be some small Error, and the third Day another, and the fourth another; all which added will make the Error considerable. For Example, if in one Day there be an Error only of four Minutes, which will be in the best Clock they have yet made, the Error in the Longitude will be one Degree; and the next Day another, &c. Therefore this Method is justly neglected by Seamen; and at the Time I am writing, there are some at the *Hague* who promise to the States a true Piece of Clock-work; but it being examined by Men skilled in these Things, it is found insufficient (*b*).

L E M M A.

(*b*) There is another great Difficulty in the use of Clocks for discovering the Longitude: because how perfect soever they may be made, yet they will shew the Hours in Places of different Latitudes, different from those of the Place they were made for. Thus for Example, if a Clock fitted for *Paris* were to approach the Equator, it would there shew the Hour slower by one twentieth Part, according to the Observations of M. *Richer**, or more than three or four Minutes according to M. *Hayes* and *Couplet*†, than at *Paris*. And hence proceeds that Retardation of the Motion of the Pendulum of the Clock, towards the Equator, as mentioned *Chap. iii.* And Mathematicians by reasoning according to the Principles there laid down, shew how much the Motion of a Clock may be retarded, according to the Diminution of the Latitude of the Place. But as in this Matter they are obliged to

* See *Hist. Acad. Reg.* by *du Hamel*, p. 110.

† *Hist. de l'Acad. Roy.* 1700, 1701.

L E M M A.

BECAUSE in each of the foregoing Methods the Hour is to be found at the Place where the Observations are made, we shall show, from Astronomy, how that may be done; the Elevation of the Pole being given, the Sun is to be used by Day, and the Stars by Night, and in both Times 'tis best to observe when they come to the Meridian, and use a good Clock for the intermediate Time: for in half a Day there will be but a small Error, if care be taken: and so we have no need of the Latitude, tho' 'tis wanted afterwards to find the Parallel of the Place.

BY Day we know 'tis twelve when the Sun comes to the Meridian, and then the Clock is to be brought to 12; but if the Hour be taken before twelve, bring the Clock to it; and observe when the Sun comes to the South, and the Clock will show the Hours since the Observation, and so the Hour that was then.

BUT if you observe the Sun out of the Meridian, and take it's Altitude, you will have a spherical Triangle, in which is known the Complement of the Latitude, the Complement of the Declination, and the Complement of the Altitude; whence you may find the Angle between the two first by spherical Trigonometry. We showed, *Prop. xxiii. Chap. xxix.* how to do it by the

use an Hypothesis, which themselves do not allow certain, the Proportion they assign cannot be relied on for discovering the Longitude of Places with any exactness. It remains therefore to be discovered, by accurate Observations

made in all Parts, in what Proportion Clocks are retarded according to the different Latitudes; that the Hour shewn may be reduced to the true Hour of the Place departed from.

Globe,

Globe, which may be sufficient for a Geographer; but Seamen must find it by Calculation: tho' some find it by an Universal Planisphere; but I fear there will be an Error of some Minutes. By Night the Stars are to be used; and some one or other may be found then in the South, or we may wait 'till one comes to it; then take the right Ascension of the Sun and Star, subtract the former from the latter; but if greater, add it's Complement to three hundred and sixty to the Star's Ascension; and turn the Degrees to Hours and Minutes.

PROPOSITION VIII.

To explain other Methods of finding the Longitude, which properly give us not the Longitude itself, but the Point we are in, whose Longitude is wanted, which is of use to determine the Longitude.

The first Method.

Having the Distance of two Places, and the Latitude of both Places, to find the Difference of their Longitude; or the Point of the one being given in the Map or Globe, to find the other.

IF we use trigonometrical Calculation, we must find the Angle in the spherical Triangle, which hath three Sides known, *i. e.* the Angle between the Complements of the two Latitudes, or opposite to the Distance turned to Degrees.

BUT by the Globe and Map thus. Take the Distance, turned to Degrees, with the Compasses on the Globe, and fixing one Leg at the Place given, cut the Parallel of the other in a Point thro' which a Meridian being drawn, will be the Meridian of the other. But Maps, even Sea-Charts,
are

are not so proper or ready for this Method, as not giving the Distance accurately.

The second Method.

Having the Point given, that one Place lies in from another, and the Latitude of both Places, to find the Longitude of the other, and it's Place on the Globe and Map.

BY the Point it is in we understand the Angle between the Meridian of the one, and a Line from the one Place to the other. By Trigonometry, find the Angle between the two Complements of the two Latitudes, and you have the Difference of Longitude.

ON the Globe thus: bring the known Place to the Zenith, and there apply the Quadrant of Altitude; and having drawn the Parallel of the other Place, bring the Quadrant to the Point; and where it cuts the Parallel is the other Place.

THE same way on the Map: draw the Parallel of the unknown Place, then draw a Line from the given Place to the Point in which the other is; and where that Line cuts the Parallel is the Place. If the Point a Ship sails on be enquired we must proceed otherwise, as in Chap. xxix.

The third Method.

Having the Point a Place lies in from another whose Latitude is known, with their Distance, to find the Longitude of that Place, and it's Situation on the Globe and Map.

BY Trigonometry; having the Complement of the Latitude, and the Distance in Degrees, and the Angle included between them, by having the Point

given; find the Angle opposite to the Distance, which will be the Difference of Longitude.

ON the Globe and Sea-Charts thus: bring the Place to the Zenith, and apply the Quadrant there, and bring it to the Point on the Horizon; then count the Distance on the Quadrant, from the Zenith; and a Meridian from the Pole thro' the Extremity of the Arch of Distance, is the Meridian the other Place is in. We shall show how this may be done by the Planisphere in *Chap. xxxiii.* for the Globe is not so useful at Sea.

THE same way may be used to find the Place on the Sea-Charts; but 'tis not so accurate, as we shall see in the following Chapter.

The fourth Method.

Having the Distance of an unknown Place from two other Places whose Distance from them is known.

ON the Globe: take one Distance turned to Degrees from the Equator, and one Foot being in that one Place, describe an Arch, and with the Distance of the other, and one Foot in the other Place, cut that Arch; and the Point of Intersection is the other Place.

AND the same way on the Map; only the Distance is not to be turned to Degrees, but taken from the Scale of Miles; but if the Place be very remote there will be a considerable Error: for the Maps do not perform this accurately.

TO work by Calculation is difficult, and requires a Figure; and is better learned from a Master than by reading.

The fifth Method.

Having two Places on the Earth, and the Points in which a third Place is situated from them, to find it's Place on the Globe and Map, and it's Longitude by Calculation.

ON the Globe: bring one Place to the Zenith, and apply there the end of the Quadrant of Altitude; bring it to the Point on the Horizon; and draw a Line (or a vertical Circle from the Zenith) along the Edge of the Quadrant; and do the same with the other Place; and where the Quadrant cuts the first vertical Circle is the Place of the other.

AND the very same way may be used for finding it on the Map.

THE Calculation of it we leave to a Master, if he find a Scholar that is capable of it.

BUT enough is said of finding the Longitude, whose great Use we have shown under *Prop. ii.*

WE here add a Table of the Latitude and Longitude of the chief Places of the Earth, that Students may have wherewith to exercise themselves. This Table is also useful in every Part of Geography. The Author's Table, which was very erroneous, is here omitted; and a new and exact one, agreeable to more late and careful Observations, added in it's stead.

M 2

A TABLE

A TABLE of the Latitude and Longitude of the most remarkable Places in the World, from the latest and best Observations, the Longitude accounted from the Meridian of London.

Note, All the Places that have S annexed to their Latitude, are in South Latitude, and all the rest are North from the Equinoctial. Also, all the Places whose Longitude are marked W, are in West Longitude from the Meridian of London, and all the rest East.

<i>Names of Places.</i>	<i>Latitude</i>	<i>Longitude</i>
<i>A</i>	<i>D. M.</i>	<i>D. M.</i>
A bbeville, Picardy France	50 9 N	2 24 E
Achin, Sumatra East Indies - - - - -	4 40 N	93 15 E
Adrianople, Turkey in Europe - - - -	43 33 N	27 24 E
Agra, a Capital in the Mogul's Empire -	29 0 N	79 24 E
Aix, Provence France	43 4 N	5 44 E
Aix la Chapelle Germany - -	50 48 N	7 0 E
Aleppo, Levant Asia	37 0 N	41 20 E
Alexandria, Egypt Africa - - - - -	31 25 N	30 50 E
Alexandretta, or Scanderoon - - - -	37 10 N	37 50 E
Algiers, Barbary Africa - - - - -	36 20 N	2 10 E
		Amiens

Names of Places.	Latitude		Longitude	
	D.	M.	D.	M.
Amiens, Picardy Fr.	49	30 N	2	50 E
Amsterdam, Holland	52	29 N	5	4 E
Ancona, Italy - - -	43	30 N	14	30 E
Antibe, Provence Fr.	43	15 N	8	9 E
Antwerp, Brabant -	51	16 N	4	10 E
Appenrade, Sleswick				
Denmark - - - - -	55	26 N	10	30 E
Archangel, Russia -	64	50 N	40	10 E
Arica, Peru South				
America - - - - -	18	50 S	74	50 W
Arles, Provence Fr.	43	15 N	4	40 E
Arras, Artois France	50	16 N	2	30 E
Astracan, by the Cas-				
pian Sea Muscovy	46	50 N	51	30 E
Athens, Greece - - -	37	25 N	23	40 E
Avignon, Provence				
France - - - - -	43	15 N	4	40 E
Aufburg, Suabia Ger-				
many - - - - -	47	55 N	10	45 E
B				
Babylon, Chaldea	31	56 N	43	50 E
Baden, Suabia				
Germany - - - - -	48	38 N	8	0 E
Bagdat Mesopotamia	33	0 N	45	20 E
Baldivia, Chili South				
America - - - - -	40	0 S	78	0 W
Barbadoes, West-				
Indies - - - - -	13	10 N	59	48 W
Barcelona, Catalonia				
Spain - - - - -	41	10 N	2	0 E
	M 3			Barleduc,

<i>Names of Places.</i>	Latitude			Longitude		
	D.	M.		D.	M.	
Barleduc, Champagne						
France - - - - -	48	44	N	4	5	E
Basil, Switzerland - -	47	34	N	8	4	E
Batavia, Java E. Ind.	6	15	S	100	50	E
Bayonne, Gascony Fr.	43	30	N	1	10	W
Belgrade, Servia - - -	45	0	N	18	20	E
Bengal, India - - - - -	21	0	N	88	0	E
Bergamo, Italy - - -	45	43	N	9	45	E
Bergen, Norway - -	60	0	N	5	25	E
Berlin, Upper Saxony						
Germany - - - - -	52	10	N	13	30	E
Bilboa, Biscay Spain	43	10	N	3	0	E
Bologna, Italy - - -	44	30	N	11	40	E
Bologne, Picardy Fr.	50	36	N	1	50	E
Boston, New-Engl. -	42	10	N	67	0	W
Bordeaux, Guienna						
France - - - - -	44	55	N	0	45	E
Brandenburg, Upper						
Saxony Germany -	52	10	N	12	30	E
Brest, Bretagne Fr.	48	34	N	4	28	W
Bremen, Westphalia						
Germany - - - - -	53	0	N	8	48	E
Breslaw, Bohemia						
Germany - - - - -	51	5	N	16	35	E
Bristol, England - -	51	33	N	2	34	W
Brill, Holland - - -	51	55	N	6	15	E
Bruges, Flanders - -	51	15	N	3	0	E
Brunswic, Germany	51	55	N	11	30	E
Brussels, Flanders - -	50	48	N	4	5	E
Buda, lower Hungary	47	0	N	16	55	E

Cadiz

<i>Names of Places.</i>	<i>Latitude</i>			<i>Longitude</i>		
<i>C</i>	<i>D. M.</i>			<i>D. M.</i>		
C Adiz, Andalusia						
Spain - - - -	36	5	N	5	40	W
Cairo, Egypt Africa	30	10	N	31	30	E
Cagliari, Sardinia - -	39	10	N	9	26	E
Calais, France - - - -	50	57	N	1	50	E
Calmar, Sweden - - -	56	55	N	17	20	E
Calecute, East Indies	11	0	N	74	50	E
Cambodia, India - -	10	20	N	108	0	E
Cambray, France - -	50	10	N	3	15	E
Candia, in Candia Isl.	34	55	N	24	50	E
Canterbury, England	51	10	N	1	6	E
Candia, Ceylon East						
Indies - - - - -	7	30	N	80	30	E
Cape of Good Hope -	34	15	S	19	50	E
Cape Verd - - - - -	14	30	N	16	26	W
Cartagena, Spain - - -	37	0	N	0	28	E
Carthage, Africa - - -	35	0	N	11	0	E
Catanea, Sicily - - -	37	20	N	15	15	E
Ceuta, Africa - - - -	35	50	N	5	27	W
Ceylon, East India -	7	50	N	83	20	E
Christianstadt, Goth-						
land Sweden - - - -	56	35	N	14	36	E
Cochin, Malabar Ind.	10	0	N	75	18	E
Cochin, China E. Ind.	13	0	N	107	0	E
Cologne, Germany -	50	40	N	7	10	E
Compostella, Galicia						
Spain - - - - -	42	45	N	8	15	W
Constantinople - - - -	41	40	N	29	40	E
Copenhagen, Zeland						
Denmark - - - - -	55	40	N	12	35	E
	M 4			Cork,		

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Cork, Ireland - - -	51 45 N	8 0 W
Corinth, Morea Turkey	38 0 N	22 25 E
Cormandel, India - -	8 0 N	78 20 E
Cracow, Poland - -	50 15 N	20 50 E
Cremona, Italy - - -	45 10 N	10 32 E
Cusco, Peru - - -	12 25 S	73 40 W
Cyprus Island, Levant	35 0 N	34 0 E
D		
Antzic, Poland	54 25 N	19 30 E
Dardanel, Tur.	40 0 N	28 0 E
Delft, Holland - -	52 10 N	4 10 E
Derbent, by the Cas- pian Sea - - -	42 0 N	50 0 E
Dieppe, France - - -	49 56 N	0 57 E
Dort, Holland - -	51 45 N	4 30 E
Doway, Flanders - -	50 12 N	3 30 E
Dresden, Saxony -	51 6 N	13 50 E
Droutheim, Norway	63 0 N	10 15 E
Dublin, Ireland - - -	54 50 N	7 20 W
Dunkirk, France - -	51 7 N	2 30 E
Durazzo Albania Tur.	40 40 N	17 45 E
Dussledorp, Westphal.	51 0 N	7 5 E
E		
Dinburgh, Scotl.	55 56 N	3 0 E
Ebbing Poland	54 20 N	20 30 E
Elfinborg, Schonen Sweden - - -	56 0 N	13 10 E
Elfineur, Zeland Den- mark - - -	56 0 N	13 6 E
Embden, Westphalia Germany - - -	53 10 N	7 15 E
		Enchuy-

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Enchuyſen, Holland	52 50 N	4 30 E
Epheſus, Natolia Aſia	37 50 N	27 35 E
Erfort, Saxony Germ.	50 40 N	11 30 E
F		
Errara, Italy - - -	44 45 N	12 10 E
Ferro, Canaries	28 5 N	18 10 W
Fez, Barbary Africa	33 15 N	3 50 E
Florence, Tuſcany		
Italy - - -	43 40 N	11 35 E
Fontarabia, Biſcay Sp.	43 0 N	1 40 W
Frankford, on the O-		
der Germany - - -	52 28 N	14 35 E
Frankfort, on the		
Main Germany -	49 45 N	9 45 E
Freiberg, Suabia Ger-		
many - - -	47 50 N	8 10 E
Furſtenburg, Suabia		
Germany - - -	47 15 N	9 15 E
G		
Allipoli, Roma-		
nia Turkey - -	40 55 N	28 20 E
Geneva, Savoy Italy	46 15 N	6 12 E
Genoa, Italy -	44 25 N	9 22 E
Ghent, Flanders -	51 6 N	3 35 E
Gibraltar, Spain -	35 50 N	5 35 W
Giron, Catalonia Sp.	41 45 N	3 12 E
Glaſgow, Scotland - -	56 20 N	4 18 W
Gneſna, Poland -	52 25 N	18 32 E
Goa, Eaſt-Indies - -	15 30 N	73 50 E
Gombroon, Perſian		
Gulph - - -	7 10 N	56 0 E
		Gotten-

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Gottenburg, Sweden	57 30 N	12 0 E
Granada, Granada Sp.	36 20 N	2 45 E
Grenoble, Dauphiné France - -	45 10 N	5 40 E
Grodno, Lithuania Poland - -	53 25	25 4 E
Groeningen, Holland	53 5 N	5 45 E
Guadaloupe, America	14 0 N	62 15 W
H ague, Holland	52 10 N	4 0 E
Hamburg, Ger- many - -	53 30 N	10 0 E
Hanover, Saxony Germany - -	52 16 N	9 0 E
Harlem, Holland -	52 25 N	4 15 E
Heidelberg, Lower Rhine Germany -	49 12 N	8 45 E
St Helen's Island -	15 55 S	7 0 W
Helmstadt, Saxony Germany - -	51 52 N	12 10 E
Hildesheim, West- phalia Germany -	51 45 N	10 15 E
Hoen, Zolern Suabia Germany - -	48 40 N	9 10 E
I S t J ago, Spain -	42 58 N	9 52 W
James-Town, Virginia Nor. America - -	37 10 N	75 0 W
Jerusalem, Palestine Asia - -	32 44 N	35 15 E
		Ingol-

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Ingolstadt, Bavaria		
Germany - -	48 32 N	13 0 E
Inspruc, Austria Ger-		
many - -	47 40 N	14 45 E
Ispahan, antient Par-		
thia Persia - -	33 0 N	53 10 E
Juliers, Westphalia	50 20 N	6 45 E
K		
Affa, Crim Tar-		
tary - -	46 0 N	36 50 E
Kaminiack, Podolia		
Poland - -	49 20 N	24 35 E
Kargapol, Russia -	61 30 N	42 15 E
Kexholin, Finland		
Sweden - -	61 20 N	31 0 E
Kiow, Ukrain Poland	50 30 N	32 45 E
Koningburg, Prussia		
Poland - -	54 55 N	22 15 E
Konizeck, Poland -	54 15 N	18 50 E
L		
Ansperg, Poland	52 55 N	15 25 E
Landau, Suabia		
Germany - -	48 50 N	8 10 E
Laodécia, Natolia Asia	38 10 N	29 30 E
Leghorn, Italy —	43 40 N	11 10 E
Lemburg, Poland -	49 50 N	25 15 E
Leopoldstat, Hungary	48 45 N	18 40 E
Lepanto, Achaia Tur-		
ky - -	38 30 N	20 40 E
Lewarden, W. Friess.	53 0 N	6 30 E
Leyden, Holland -	52 10 N	4 30 E
		Leipfic

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Leipfic, Germany	50 50 N	12 50 E
Liege, Spanish Pro- vinces - -	50 25 N	5 35 E
Lima, Peru South A- merica — —	11 30 S	78 40 W
Limburg, Spain -	50 20 N	6 20 E
Lintz, Austria Germ.	48 10 N	14 30 E
Lisle, Flanders -	50 40 N	2 50 E
Lisbon, Portugal -	38 45 N	8 20 W
Livorn, <i>see</i> Leghorn		
LONDON <i>Metropolis</i> of England - -	51 32 N	00 00
Loretto, Tuscany Italy	43 36 N	14 38 E
Lubeck, Holstein		
Denmark - -	54 10 N	11 20 E
Lublin, Poland - -	51 18 N	25 0 E
Lucerne, Switzerland	46 42 N	8 25 E
Lunden, Gothland		
Sweden - -	55 30 N	13 25 E
Luxemburg, Saxony		
Germany - -	53 10 N	10 40 E
Luxemburg, France	49 20 N	6 12 E
Lyons, Lyonsis Fr.	45 40 N	4 40 E
M Adagafcar -	19 29 S	43 55 E
Madrid, New		
Castile Spain - -	40 0 N	3 28 W
Maestricht, Spanish		
Provinces - -	50 34 N	5 45 E
Magdeburg, Saxony		
Germany - -	51 45 N	12 30 E
		Majorca,

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Majorca, in the Me- diterranean - -	39 00 N	2 30 E
St Maloes, Bretagne France - -	48 38 N	2 20 W
Malaga, Granada Sp.	36 00 N	3 56 W
Malta, near Sicily Me- diterranean - -	35 50 N	14 00 E
Malucca, in the East Indies - -	2 8 N	100 25 E
Mantua, Italy - -	45 16 N	11 40 E
Marpurg, Germany	50 30 N	8 50 E
Marfeilles, Provence France - -	43 15 N	5 40 E
Martinico Island, W. Indies - -	14 44 N	60 55 W
Mentz, Germany -	49 44 N	8 15 E
Messina, Sicily - -	38 10 N	15 40 E
Metz, Lorrain Germ.	48 50 N	6 6 E
Mexico, N. America	10 00 N	104 0 W
St Michael, <i>see</i> Ar- changel - -	-	-
Milan, Italy - -	55 45 N	24 0 E
Minorca Island, Me- diterranean - -	39 10 N	4 0 E
Mittau, Courland -	56 25 N	25 0 E
Mocha, China - -	22 13 N	116 35 E
Modena, Italy - -	44 30 N	11 45 E
Montpelier, Langue- doc France - -	43 28 N	4 0 E
Moscow, Capital of Moscovy - -	55 30 N	39 30 E
		Moufol,

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Moufol, near old Ni- neveh - - -	34 32 N	43 0 E
Munster, Westphalia Germany - - -	51 45 N	7 45 E
Munchen, or Munic Bavaria Germany - N	47 45 N	11 35 E
N Amur, Flanders	50 10 N	4 50 E
Nancy, Lorain France - - -	48 32 N	6 40 E
Nantz, Bretagne Fr.	47 12 N	1 30 W
Nankin, China - -	31 0 N	118 30 E
Naples Italy - - -	41 45 N	14 50 E
Narva, Livonia - -	58 55 N	30 30 E
Narbonne, Langue- doc France - - -	42 50 N	3 0 E
Nassau, upper Rhine Germany - - -	50 0 N	8 0 E
New Piedmont, Italy	43 40 N	7 10 E
Nismes, Languedoc France - - -	43 30 N	4 30 E
Norwich, England -	52 45 N	1 28 E
Norkoping, Gothland Sweden - - -	58 20 N	17 30 E
Notteburg, Ingria Sweden - - -	60 0 N	32 10 E
Nuremburg, Franco- nia Germany - - -	49 0 N	11 15 E

Oleron,

<i>Names of Places.</i>	<i>Latitude</i> D. M.	<i>Longitude</i> D. M.
O		
O Leron, Gascony France -	43 0 N	0 20 W
Onspack, or Anspeck Franconia Germ.	48 50 N	10 32 E
Orange, Provence France — —	44 10 N	4 45 E
Oran, Barbary Africa	35 30 N	0 5 W
Ormuz, Persia - -	27 30 N	61 30 E
Ofnaburg, Westphalia Germany - -	51 10 N	8 20 E
Oudenard, Flanders	50 46 N	3 20 E
Oxford, England -	51 48 N	1 12 E
P		
P Adua, Italy - -	35 32 N	12 25 E
Paderborn West- phalia Germany -	51 30 N	9 0 E
Palermo, Sicily - -	37 26 N	13 45 E
Pampelona, Spain -	42 30 N	1 15 E
Panama, America -	1 19 S	82 30 W
Paris, France - -	48 45 N	2 20 E
Parma, Italy - -	44 42 N	11 0 E
Pekin, China - -	39 52 N	110 50 E
Perpignan, Catalonia Spain - -	42 30 N	3 0 E
Pergamos, Natolia A- sia - -	37 50 N	29 10 E
Peter Waradin, Scla- vonian - -	45 0 N	17 40 E
Philipopoli, Romania Turkey - -	42 30 N	24 35 E
		Philadel.

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Philadelphia, Natolia		
Afia - - -	38 35 N	29 35 E
Pignerol, upper Dau-		
phiné France - -	44 48 N	7 32 E
Piombino, Tuscany		
Italy - - -	42 54 N	11 10 E
Pisa, Tuscany Italy	43 55 N	11 12 E
Placentia, Parma Italy	44 50 N	10 15 E
Pleskow, Russia -	58 10 N	33 55 E
Poictiers, Orleanois		
France - - -	46 30 N	0 20 E
Port, or Oporta Por-		
tugal - - -	40 52 N	7 50 W
Port-Royal, Jamaica	17 40 N	75 55 W
Prague, Bohemia -	50 0 N	14 25 E
Presburg, Hungary -	48 22 N	15 30 E
Q uebec, Canada	47 10 N	70 15 W
R agusa, Dalma-		
tia Turkey -	42 25 N	16 30 E
Ratisbon, Bavaria -	48 34 N	12 10 E
Regio, Calabria Italy	38 40 N	16 10 E
Rheims, Champagne		
France - - -	49 20 N	3 55 E
Rhodes, Island Ar-		
chipelago - - -	35 30 N	29 15 E
Riga, Livonia - -	57 0 N	24 48 E
Roan, France - -	49 27 N	0 57 E
Rochel, Orleanois Fr.	45 55 N	0 50 W

ROME,

<i>Names of Places.</i>	Latitude			Longitude		
	D.	M.		D.	M.	
Rome, Italy - -	42	8	N	13	7	E
Roses, Catalonia Sp.	41	50	N	3	30	E
Rostock, Germany -	54	10	N	12	50	E
Rotterdam, Holland	51	50	N	4	12	E
S						
Saltzburg, Bavaria						
Germany -	47	20	N	13	26	E
Salamanca, Leon Sp.	40	45	N	4	50	E
Salonichi, or Theffalo-						
nica Turkey - -	40	42	N	22	45	E
Sallee, Africa - -	22	25	N	7	45	E
Samarcand, Tartary	40	0	N	63	45	E
Saragossa, Arragon Sp.	41	20	N	0	45	W
Sardis, Natolia Asia	38	10	N	29	5	E
Scanderoon, <i>see</i> Ale-						
xandretta.						
Scaffhausen, Switzer-						
land Germany -	47	28	N	8	45	E
Selines, <i>see</i> Athens.						
Seville, Andalusia Sp.	37	0	N	5	0	W
Siam, East Indies -	14	5	N	100	50	E
Sleswic, Denmark	55	57	N	9	40	E
Smolensko, Muscovy	54	55	N	33	30	E
Smyrna, Natolia Asia	38	4	N	29	6	E
Soissons, France -	49	20	N	3	30	E
Spires, upper Rhine						
Germany - -	49	0	N	8	10	E
Stetin, Pomerania -	53	28	N	14	30	E
Stockholm, Sweden	59	30	N	19	5	E
Straßburg, Germany	48	17	N	7	52	E
Syracuse, Sicily -	35	15	N	15	0	E
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<i>Names of Places.</i>	<i>Latitude</i> D. M.	<i>Longitude</i> D. M.
T		
T Angier, Barbary Africa -	35 45 N	6 0 W
Tarragon, Catalonia Spain -	40 55 N	1 20 E
Temefwaer, Hungary	45 30 N	18 40 E
Tetuan, Africa -	35 30 N	5 30 W
Toulouse, Languedoc France -	43 15 N	1 45 E
Thorn, Poland -	53 0 N	19 32 E
Thyatira, Natolia A- fia -	38 28 N	28 32 E
Tyrol, Austria Germ.	46 15 N	10 50 E
Toledo, New-Castile Spain -	39 30 N	3 30 W
Torneo, or Torno Lapland -	65 50 N	23 30 E
Tours, Orleanois Fr.	47 10 N	0 56 E
Toulon, Provence Fr.	43 0 N	6 8 E
Tournay, Flanders	50 35 N	3 28 E
Trent, Austria Germ.	45 50 N	11 36 E
Treves, or Triers, lower Rhine Germ.	49 30 N	6 42 E
Tripoly, Barbary Afr.	33 5 N	13 50 E
Tubingen, Germany	48 34 N	9 20 E
Tunis, Barbary Afr.	35 30 N	12 40 E
Turin, Piedmont Italy	44 50 N	7 42 E
V		
V Alence, Dau- phiné France	45 0 N	4 52 E
Valencia, Spain -	39 15 N	0 10 E
		Vallado-

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Valladolid, Old Ca- stile Spain - -	41 28 N	3 50 W
Vendosme, Orlea- nois France - -	47 45 N	1 6 E
Venloe, Gelderland	51 10 N	6 8 E
Venice - -	45 36 N	12 50 E
Verdun, Lorrain Ger- many — —	49 10 N	5 20 E
Verona, Italy — —	45 25 N	12 0 E
Vienna, Austria Ger- many — —	48 12 N	16 45 E
Ulm, Suabia Germ.	47 55 N	10 8 E
Upsal, Sweden —	59 55 N	18 30 E
Urbino, Italy —	43 44 N	13 15 E
Utrecht, Holland — W	52 0 N	5 0 E
W Arfaw, Poland	52 10 N	22 0 E
Waradin, <i>see</i> Peter Waradin		
Wardhuys, Norway	71 8 N	29 0 E
Waterford, Ireland	53 0 N	7 8 W
Weimer, Saxony Ger- many — —	50 42 N	12 5 E
Wesel, Westphalia Germany — —	51 32 N	6 30 E
Wiborg, Jutland Den- mark — —	56 25 N	9 20 E
Wiborg, Finland Swe- den — —	60 50 N	30 0 E
Wisbuy, Gothland Sweden — —	57 30 N	20 0 E
	N 2	Witten-

<i>Names of Places.</i>	Latitude D. M.	Longitude D. M.
Wittenburg, Saxony Germany —	51 28 N	13 15 E
Wolfembuttle, Brunf- wic Germany —	51 50 N	10 45 E
Wormes, Germany	49 12 N	8 28 E
Wirtzburg, Franconia Germany — —	49 20 N	10 10 E
Y ork, England	53 20 N	0 48 W
Yvica, Mediter- ranean — —	38 40 N	1 10 E
Z ell, Lunenburg Germany —	52 30 N	10 26 E
Zutphen, Gelderland Holland — —	52 4 N	6 6 E

THE great Use of the Table of Latitudes, we have sufficiently explained in the preceding Proposition; and also the famous Use of the Longitudes of Places in the end of *Prop.* iii. of this Chapter. For Example, having the Hour when an Eclipse is to be in one Place, or when the Sun enters *Aries*, or when the Sun and Moon are in Conjunction, or the Hour of the Appulse of the Moon to a fixed Star; to find the Hour when the same will happen in another Place, whose Longitude is marked in the Tables. This is done by turning the Difference of Longitude into Hours, and adding it to the other Place, if less, but subtracting if more; which will give the Hour when the Phænomenon happens in the other Place.

BUT

BUT the principal Use of this Table will appear in the following Chapter.

AND seeing the Use of the Declination and right Ascension of the fixed Stars is very necessary in Geography and Navigation; we here add a Table of them; for the Year 1710. 'Tis known in Astronomy, that there is a Change in these, by reason of the Motion of the fixed Stars on the Axis of the Ecliptic. 'Tis proper to have a Table of a great many Stars; for the same Stars are not always above the Horizon at Night. We add them here, chiefly for the Practice of young Students, that they may work the Problems. This belongs to Astronomy, but is also of great Use in Geography and other Sciences.

BY Astronomy we find the Declination and right Ascension for each Year. The Tables follow.

A Table of the Sun's Right Ascension.

Days.	Janu.		Febru.		March		April		May		June	
	☉ Right Ascension.		☉ Right Ascension		☉ Right Ascension.		☉ Right Ascension		☉ Right Ascension		☉ Right Ascension	
	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.
1	19	36	21	43	23	29	01	22	03	15	05	20
2	19	40	21	47	23	33	01	26	03	19	05	24
3	19	44	21	51	23	37	01	30	03	23	05	28
4	19	49	21	55	23	40	01	34	03	27	05	32
5	19	53	21	59	23	44	01	37	03	31	05	37
6	19	57	22	03	23	47	01	41	03	35	05	41
7	20	01	22	07	23	51	01	45	03	39	05	45
8	20	05	22	11	23	54	01	48	03	44	05	49
9	20	09	22	15	23	58	01	52	03	47	05	53
10	20	14	22	18	00	02	01	55	03	51	05	57
11	20	18	22	22	00	06	01	59	03	55	06	01
12	20	23	22	26	00	09	02	03	03	59	06	05
13	20	27	22	30	00	13	02	07	04	03	06	09
14	20	31	22	34	00	16	02	11	04	07	06	13
15	20	35	22	37	00	20	02	14	04	11	06	18
16	20	39	22	41	00	24	02	18	04	15	06	22
17	20	43	22	45	00	27	02	22	04	19	06	27
18	20	47	22	49	00	31	02	26	04	23	06	30
19	20	51	22	53	00	34	02	30	04	27	06	34
20	20	55	22	56	00	38	02	33	04	31	06	39
21	20	59	23	00	00	42	02	37	04	35	06	42
22	21	04	23	04	00	45	02	41	04	39	06	47
23	21	08	23	07	00	49	02	45	04	43	06	51
24	21	12	23	11	00	53	02	49	04	47	06	55
25	21	16	23	15	00	56	02	52	04	51	06	59
26	21	20	23	18	01	00	02	56	04	55	07	03
27	21	24	23	22	01	04	03	00	04	59	07	07
28	21	28	23	26	01	07	03	04	05	03	07	11
29	21	32			01	11	03	08	05	07	07	15
30	21	36			01	15	03	11	05	12	07	20
31	21	39			01	18			05	16		

A Table of the Sun's Right Ascension.

Days.	July		August		Septem.		October		Novem.		Decem.	
	☉ Right Ascension		☉ Right Ascension		☉ Right Ascension		☉ Right Ascension		☉ Right Ascension		☉ Right Ascension	
	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.
1	07	24	09	26	11	20	13	09	15	08	17	16
2	07	28	09	30	11	24	13	13	15	12	17	21
3	07	32	09	34	11	27	13	16	15	16	17	26
4	07	36	09	38	11	31	13	20	15	20	17	30
5	07	40	09	41	11	34	13	23	15	24	17	35
6	07	44	09	45	11	37	13	27	15	28	17	39
7	07	48	09	49	11	42	13	31	15	32	17	43
8	07	52	09	52	11	45	13	35	15	37	17	47
9	07	56	09	56	11	49	13	39	15	41	17	52
10	08	00	09	59	11	50	13	42	15	46	17	57
11	08	04	10	03	11	56	13	46	15	50	18	01
12	08	08	10	07	12	00	13	50	15	54	18	06
13	08	12	10	11	12	03	13	54	15	59	18	10
14	08	16	10	15	12	07	13	58	16	03	18	15
15	08	20	10	18	12	10	14	01	16	08	18	20
16	08	24	10	22	12	14	14	05	16	12	18	24
17	08	28	10	26	12	18	14	09	16	16	18	29
18	08	32	10	29	12	21	14	13	16	20	18	34
19	08	36	10	33	12	25	14	17	16	24	18	38
20	08	40	10	36	12	28	14	21	16	29	18	34
21	08	44	10	40	12	32	14	25	16	33	18	46
22	08	48	10	44	12	36	14	29	16	37	18	50
23	08	52	10	48	12	39	14	33	16	41	18	55
24	08	56	10	51	12	43	14	37	16	45	18	59
25	08	59	10	54	12	46	14	40	16	50	19	04
26	09	03	10	58	12	50	14	44	16	54	19	08
27	09	07	11	02	12	54	14	48	16	58	19	12
28	09	11	11	05	12	58	14	52	17	03	19	17
29	09	15	11	09	13	02	14	56	17	07	19	21
30	09	18	11	12	13	06	15	00	17	12	19	26
31	09	22	11	16			15	04			19	31

A Table shewing the Right Ascension, Declination, and Magnitude of the Principal Fixed Stars.

Names of the Stars.	Magnit.	Right Ascens.		Declination.	
		H.	M.	D.	M.
P ole Star — — — — —	2	00	32	87	51 N
Girdle of Andromeda — — —	2	00	50	33	50 N
Bright Star of Aries — — —	2	01	52	22	10 N
Medusa's Head — — — — —	2	02	49	39	54 N
Right side of Perseus — — —	2	03	05	48	52 N
Aldebaran, or Bull's Eye — —	1	04	18	15	55 N
Capella, or the Goat — — —	1	04	55	45	41 N
Bright Foot of Orion — — —	1	05	01	08	33 S
Middle Star in Orion's Belt —	3	05	20	01	25 S
Orion's Right Shoulder — — —	1	05	39	07	19 N
Auriga's Right Shoulder — — —	2	05	44	44	53 N
Bright Foot of Gemini — — —	2	06	19	16	38 N
Syrius, or the Great Dog — —	1	06	33	16	21 S
Castor, or Northmost Twin —	2	07	16	32	27 N
Procyon, or the Little Dog —	2	07	24	05	54 N
Pollux, or Southmost Twin —	2	07	25	28	39 N
Hydra's Heart — — — — —	1	09	14	07	29 S
Lyon's Heart, or Regulus — —	1	09	54	13	16 N
The Lower of the Pointers — —	2	10	41	57	50 N
The Upper of the Pointers — —	2	10	43	63	13 N
Lyon's Tail — — — — —	1	11	31	16	05 N
Upper of two last in the Square of the Great Bear — — — —	2	12	02	58	34 N
Last but two in the Great Bear's Tail — — — — —	2	12	40	57	27 N
Virgins Spike — — — — —	1	13	11	09	44 S

Last

Names of the Stars.	Magnit.	Right Ascens.			Declination.	
		H.	M.	D.	M.	
<i>Last but one in the Great Bear's Tail</i>	2	13	10	56	21	N
<i>Last in the Great Bear's Tail</i>	2	13	34	50	42	N
<i>Arcturus</i>	1	14	02	20	38	N
<i>South Ballance</i>	2	14	32	14	54	S
<i>Foremost Guard</i>	2	14	51	75	15	N
<i>Brightest of the Crown</i>	2	15	21	27	38	N
<i>Brightest of the Serpent's Neck</i>	2	15	33	07	18	N
<i>Antares, the Scorpion's Heart</i>	1	16	12	25	47	S
<i>Head of Hercules</i>	3	17	02	14	43	N
<i>Ophincus, or Serpent's Head</i>	3	17	22	12	47	N
<i>Lyra, or the Harp</i>	1	18	27	38	33	N
<i>Swan's Bill</i>	3	19	17	27	29	N
<i>Vulture, or Eag's Heart</i>	2	19	34	08	10	N
<i>Swan's Tail</i>	2	20	30	44	19	N
<i>Mouth of Pegasus</i>	3	21	27	08	39	N
<i>Fomelbaut</i>	1	22	41	31	03	S
<i>Marchab, or Pegasus Wing</i>	2	22	48	13	44	N
<i>Scheat, or Pegasus Leg</i>	2	22	50	26	36	N
<i>Cephus's Knee</i>	3	23	20	76	07	N
<i>Andromeda's Head</i>	2	23	53	27	35	N
<i>End of Pegasus Wing</i>	2	23	57	13	39	N

The Explanation and Use of the Tables of the Sun's Right Ascension, and of the Right Ascension and Declination of the fixed Stars.

FOR the Table of the Sun's Right Ascension, seek the Month at the Top, and the Day in the left Hand Column, and in the common Angle, is the Sun's Right Ascension. *Example*, on the 17th of July, the Sun's Right Ascension is 8 Hours 28 Minutes.

IN

IN the Table of fixed Stars, the first Column is the Names of the Stars; the second, the Magnitude; the third, the Right Ascension in Hours and Minutes; and the fourth, the Declination in Degrees and Minutes. *Example*, the *Virgin's Spike* is of the first Magnitude, Right Ascension 13 Hours 11 Minutes, Declination 9 Degrees 44 Minutes South, &c.

I. *To find the time of a Star's coming upon the Meridian.*

SUBTRACT the Right Ascension of the Sun, from the Right Ascension of the Star, (adding 24 Hours to the Right Ascension of the Star, if Subtraction cannot otherwise be made) the remainder is the time of the Stars coming to the Meridian.

EXAMPLE. I desire to know what time the Great Dog comes to the Meridian, *December* the 25th.

	H.	M.
Right Ascension of the Great Dog —	6	33
Right Ascension of the Sun — —	19	4
Remainder (24 Hours being added to the Right Ascension of the Great Dog.) — — — —	11	29

THE Great Dog souths 29 Minutes past 11 at Night.

II. *By the Altitude of a Star, when upon the Meridian, to find the Latitude of the Place.*

Note, In North Latitude, those Stars whose North Declination exceed the Complement of Latitude, may be observed under the Pole.

THIS may be reduced to four Rules:

I. WHEN

1. WHEN the Star is between the Horizon and the Equinoctial, subtract the Declination from the Complement of Altitude (commonly called the Zenith Distance) the Remainder is the Latitude of the Place. *Example.*

	D.	M.
Suppose the Complem. of Altitude be	70	30
The Declination South	40	00
The Latitude is	30	30

2. WHEN the Sun or Star is between the Equinoctial and the Zenith, add the Complement of Altitude to the Declination, the Sum is the Latitude of the Place. *Example.*

	D.	M.
Let the Complement of Altitude be	35	00
The Declination North	10	00
The Latitude is	45	00

3. WHEN the Sun or Star is between the Zenith and the elevated Pole, subtract the Zenith Distance, or Complement of Altitude from the Declination, the Remainder is the Latitude. *Example.*

	D.	M.
If the Declination be	20	00
The Complement of Altitude	10	45
The Latitude of the Place is	9	15

4. WHEN the Sun or Star is between the elevated Pole and the Horizon, or, which is the same, when the Sun or Star can be seen under the Pole. Add the Altitude of the Sun or Star to the Complement of it's Declination, the Sum is the Latitude of the Place. *Example.*

Sun's

	D.	M.
Sun's Altitude above the Horizon —	5	00
Declination $22^{\circ} 00''$ it's Complem. —	68	00
The Sum is the Latitude —	73	00

Note, The Complement of Altitude, which is the Zenith Distance, is what remains, when the Altitude of the Sun or Star is taken from 90 Degrees.

Example.

	D.	M.
From —————	90	00
Subtract the Altitude suppose —	46	10
Remains the Zenith Distance —	43	50





C H A P. XXXII.

Of the mutual Situation of Places, and of the making of Globes and Maps.

P R O P O S I T I O N I.

Having a given Place on the Earth, to find how another Place bears from it.

THAT is, to find the Point it is in, or the Angle of Position made by the Meridian, and an Arch from the one Place to the other: For Example; suppose we are at *Amsterdam* and desire to know how *Rome, Constantinople, Stockholm, &c.* lie from it.

The first Method.

W H E R E you can see one Place from another, 'tis easily done, by a Semicircle placed horizontally, and directing the Index on it to the Place; then observe what Angle that Line makes with the Meridian Line, first found; which may be turned to Points, allowing eleven Degrees and a Quarter for a Point; and so every Place may be observed round you. We may next go to another Place, and from that observe, how all the Places in view bear from us; which will determine each Place in a Map, by the cutting of two Lines.

The

The second Method.

IF you have the Places proposed on the Globe, bring the given Place to the Meridian, and elevate the Pole for it's Latitude; and fixing the Quadrant of Altitude in the Zenith, bring it to the several Places successively. The Quadrant will show on the Horizon, the Angle of Position and the Point wanted: thus we may tell how *Rome*, or *Constantinople*, lies from *Amsterdam*: which that we may conceive on the Earth, we must know which way the North lies; and so how the other Points lie.

The third Method.

ON right lined Maps: if the proposed Places be found in them, their Situation towards one another may be seen by the Eye, a right Line being conceived to go thro' the Place, North and South; and another crossing it at the Place at right Angles, shows the East and West: from which the intermediate Points may be conceived. Or by sweeping an Arch, or Quadrant, with the Center at one Place, you'll have their Bearings more exactly. But this holds only in particular Maps; for in general and curve-lined Maps, the Points are not found so exact as one would desire.

The fourth Method.

HAVING the Latitude and Longitude of two Places, their Bearing from the one is accurately found by spherical Trigonometry, either the common way, or by Logarithms, or by an universal Planisphere, or even by the Globe: for in a given Triangle you have the Complement of the Latitude of both Places, and the Difference of their Longitude;

rude; and the Angle wanted is that adjacent to either of the given Sides; which will show how one Place bears from the other. But this will be made plainer by a Master and a Figure, and herein appears the use of the Table of Latitudes and Longitudes.

The fifth Method.

HAVING the Latitude and Distance of two Places, to find their Situation, with respect to one another. This may be done by spherical Triangles; but there is no need of adding more on this Head.

PROPOSITION II.

Having a Place on the Earth, or on the Globe, to find all the Places that lie in the same Point from it.

FOR Example; to find the Places that lie North-East from *Amsterdam*.

ELEVATE the Globe for the Place, bring the Place to the Meridian, there apply and fix the one End of the Quadrant, turn it about to the North-East Point on the Horizon; and you have under the Margin of the Quadrant, the Half of the Places that lie North-East; and the other Half under the Horizon.

DRAW thro' the given Place a great Circle, that shall make the Angle of Position with the Meridian; and the Half of that Circle will go over the Places.

PROPOSITION III.

To find all the Places from which a given Place lies in a given Point.

FOR Example ; to know all the Places from which *Amsterdam* lies North-West : or to make it more pleasant ; having a Place, as *Amsterdam*, to find all the Places from which if I travel to *Amsterdam*, I shall still go North-West. The former Problem might be drawn on a Plane, for the Places sought are all in the Periphery of a Circle, which may be exhibited on a Plane, and are always in one Plane ; but the present is a solid Problem, or rather regards the Surface of a Solid ; for the Places lie not in a Circle, except when the Point is North or South ; but in a certain curve Line, which is to be drawn not on a Plane, but on a curve Superficies ; and is a curve Line of a particular Kind, terminated on both Sides. And to conceive it, or find the Places in it on the Globe, bring the given Place to the Meridian ; and if the Point given be eastward, the Places sought are westward ; but contrariwise, if the Point be westward, and the given Place be northerly, the Places lie southerly : but contrariwise, if southerly, and the given Point be due East or West on the Equinoctial, the Places sought will lie in a curve Line, beginning at the given Place and ending in the Pole next to it, and situated on the East Side of the Meridian, if the given Point be the West ; but on the West Side if it be East. Thus let the Places sought be those from which *Amsterdam* lies due West ; because the vertical Circle of all Places, or the Point due East and West from them, falls on a Point in the Equator, at the Horizon ninety Degrees from the Meridian of every Place ; and the Places sought must be on the East Side

Side of the Meridian ; so that their prime Vertical running to the West, may cut a Quadrant of the Equator between the West and South : now let great Circles be conceived to pass thro' *Amsterdam* from each Point of that Quadrant, and Meridians drawn from these Points as Poles : the Points in which each great Circle cuts it's Meridian, are the Places sought, which constitute a curve Line running into, and terminating in, the Pole ; where there appears to be a Difference between that Line and the Rhumb-Line of a Ship's Course, (of which we shall treat in a particular Chapter) ; for the later is not in Voyages due East and West : but all kinds of the former are such as to be contained between the Quadrants of two Meridians, whose Distance does not exceed ninety Degrees, and end in the Pole.

BUT when any Point is given between the Cardinals ; for Example, let the Places be required from which *Amsterdam* lies South-West, or in a Point forty five Degrees from the Meridian of each Place towards the West, remote from the South. First, conceive another Meridian on the East Side of the Meridian of *Amsterdam*, (for 'tis plain the Places sought must be situated there) which makes an Angle of forty five Degrees, with that of *Amsterdam* ; this will be the Bounds of the Places sought : nor can any Place be found in any Meridian beyond it, which will answer the Demand. Then imagine a great Circle drawn from *Amsterdam*, that shall be perpendicular to that Meridian ; and because the Point given inclines from the West to the South, the Places sought must be situated in the space of the Triangle, whose Sides are 1. the Perpendicular now drawn. 2. A Part of that Meridian intercepted between the great Circle and the next Pole ; and 3. Part of the Meridian of *Amsterdam*, betwixt *Amsterdam* and the nearest Pole.

THE curve Line is situated in that Space, and the Points of it answer the Demand; and it goes from *Amsterdam* all the way to the Pole in a curve Path: for to draw it there must be several Meridians drawn in that Space; and such a Point be taken in each, from which a great Circle being drawn to *Amsterdam*, makes an Angle of forty five Degrees: and thus the several Points of the Curve to be described, are found.

WE have said more of this curve Line, in our Book of curved Lines. But we would not omit it here, because this was a proper Place to explain it as belonging to Geography.

PROPOSITION IV.

Having the Latitude of one Place, and the Distance from another, and the Point in which the second lies from the first; to find the Point the other lies in from the second.

THIS will be better understood by an Example. Suppose the Point given, in which *Hamburg* lies from *Amsterdam*, and that there is wanted the Point that *Amsterdam* lies in from *Hamburg*: 'tis generally thought that it is the contrary Point, but falsely; and herein is the Error of all Sea-Charts, and right lined Maps. The true Solution is by spherical Trigonometry, or by the Globe, or the Planisphere.

PROPOSITION V.

To make a Terrestrial Globe.

THIS is the common confused Phrase for the Problem: but it ought to be proposed in a Mathematical Style thus, for understanding it distinctly,

Having any Point on the Surface of any Globe, which Point is supposed to represent a Place on the Earth (or having a Semicircle thereon), to find several Points on the Globe, and Lines which are situated to the given Point, and among themselves as the Places or Lines on the Superficies of the Earth, which they represent, are situated.

The first Method.

'TIS an excellent, easy, and accurate Method, by which, having the Latitude and Longitude of Places on the Superficies of the Globe, the Points and Places sought, representing the Parts of the Earth's Surface, are marked down. And tho' Artificers do not use this Method when they make the terrestrial Globes that are sold in great Number, (because it may be done another way, the large Sale of them answers the Expence, tho indeed it is not the more easy and less expensive way for making one Globe, yet most ready and less expensive for making a great many, of which we shall speak in the third Place); yet the Foundation of that Construction depends on this Description conceived on the Globe: and so in like manner when large Globes of Brass are to be made, and the Places of the Earth to be marked on them, such as Princes use to have, who are Lovers of Mathematics. And thus lately the *Dutch East-India* Company ordered to be made, by the Direction of *Blave*, a Globe of Brass, whose Diameter was five Foot; and on it was to be engraved, and illuminated the chief Places of the Earth, which was sent as a Present to the King of some Island there, from the said Company; the King having desired the *Dutch* Consul, that he would take care to have such a Globe made in *Holland*, promising a large Reward for it. So likewise at this present Time the famous *Frederic* Duke of

Holsace, who is not only a Favourer and Promoter of all kinds of Learning, especially Mathematics and Physics, but also a great Improver thereof: and 'tis for his Honour that I here mention that he ordered a Globe to be made of so large a Cavity, that one might commodiously sit in it, and see all the fixed Stars on the concave Surface within, marked with a Gold Colour, and the Sun in the Ecliptic, moving by a Skrew; which in the mean time revolved in twenty four Hours, by a small Instrument added to it: so that the Spectator within had such a View of the Celestial Bodies, as we have by Night in the Heavens: and the outward Surface (to come to our purpose) had the Places of the Earth on it; so that it was both a Celestial and Terrestrial Globe. When we say that the Places are to be marked on so large a Globe of Brass, Artificers cannot use their way by the Application of paper Maps: nor were it proper to do so in making such fine Globes; for the Places must be cut out and illuminated, and the Circles and Rivers marked as they are on the Earth; and that by the Table of Latitude and Longitude; using also a common Globe for giving the Rivers Course, and the Bounds of the Sea and Land.

THRO' a given Point, or one taken at pleasure, let there be drawn a great Circle for the Meridian of the Place; then take therein an Arc from that Point equal to the Latitude of the Place represented by that Point, and mark the Limit: then from the same Point on the other Side, in the same Circle, take an Arc equal to the Complement of the Latitude, or Distance of the Place from the Pole; and the Extremity of this Arc will be the North or South Pole, and the other will be in the Parallel of the Place from which on the Meridian set the Latitude, which will give the Equator. Then take on the Meridian the other Pole,

Pole, and let there be an iron Rod run thro' the two Poles; and on the ends of it let there be a Circle of Brass hung, divided accurately into three hundred and sixty Degrees, or four Quadrants, each Quadrant beginning the first Degree at the Equator, which must be also divided into three hundred and sixty Degrees; and the great Circle drawn on the Globe, may represent the first Meridian: or if you take another, let the Longitude of the Place, first set down, be set on the Equator; and at the end of the Arc draw another Circle for the first Meridian, to the West of the former, counting the Pole furthest from you the North; and you will have the East Part of the Globe on the right Hand, and the West on the left; and mark the Degrees on the Equator, ten, twenty, thirty to the right Hand, and so round; then taking the Longitude of a Place from the Table, bring the Degree, and Minute if possible, under the brass Meridian, and count the Latitude of the Place North or South; and where it ends mark the Point on the Globe under it for that Place, and so for all other Places.

YET this way is not to be wholly followed in Practice; for to make a Globe true, there should first an Axis be run through, the ends of which must be the two Poles, and the first Meridian be first drawn. Tho' 'tis seldom that large Globes are made thus from Tables; but in the common way by Paper Maps, or by taking the Latitudes and Longitudes from lesser Globes, as *Blave* did in the great one sent to the *East-Indies*.

The second Method.

THIS Method is to be used chiefly when a few Places only are to be marked on the Globe rather than for making a Globe entirely: but it makes

makes use of the Distances of Places. Let there be an Arc of a great Circle, drawn thro' a Point given; and on it take an Arc from the given Point equal to the Distance; the end of that Arc will be the other Place: and to mark a third Place, take with the Compasses the two Distances of that third Place from the other two, and having, from the two Places as Centers, described two Arches cutting one another, the Point of Intersection will be the third.

BUT this Method is not proper for the making of the whole Globe, but only when we would mark a few Places on a Globe, which had been omitted; which is easily done by the two Distances, without the Trouble of calculating their Latitudes and Longitudes. So that the Problem is this, *Having the Distance of a Place from two other Places that are found on the Globe, to mark that Place on the Globe.*

The third Method, commonly used by Artificers.

THIS third Method of making all the Globes we see (excepting the great ones above spoken of) both Celestial and Terrestrial, is indeed not very easy or quick, if there were only one or a few Globes to be made by it; but is very ready for making such a great Number of them as is sold, and is thus: Let the Superficies of the Globe and Earth be conceived as divided into twelve Parts or more, if the Globes be large, by Meridians drawn from Pole to Pole; then let there be drawn one of these Parts on a Plane, terminated with two Meridians, which will make on the Globe two Semicircles of two Meridians; and a great many Meridians been drawn thro' each Degree on the Equator, and these cut by many Portions of Parallels of Latitude thro' the Degrees on the Meridians
in

in the form of a Latitude, the middle one will be a Portion of the Equator, and the Meridians are to terminate in the Poles: and taking one for the first Meridian, mark the Degrees of Longitude on the Equator, thirty on the first Part, and from that to sixty on the other Part, and so on; thus you may find the Longitude of any Place, and it's Latitude, meeting in a Meridian and Parallel, cutting one another. And the same way the several Parts of a River or Bay may be marked; and let the same be carved out in Brass or Wood, and by a Rolling Press some thousands of them may be imprinted on Sheets of Paper; and the Parts cut out and applied to the Globe; so as the Meridian of the one may join that of the other, to make one Meridian on the Globe: and the Meridians need not reach so far as the Pole, but only to the polar Circle; and the Parts about the Poles may be covered with Papers made on purpose for them; for it will be easier to apply them that way, especially if they are large Globes. Thus are all the Places on the Earth exhibited on the Globe; and the brass Meridian, with the Horizon, Standard, Horary-Circle, and Index, are made for the Globe.

THERE are two Things in this Description that require a more full Explanation; the rest I think being easy. 1. How these twelve or twenty four Parts are described on a Plane. And, 2. how plain Papers can be applied to the curve Superficies of a Globe. The first is done easy enough. Thus, for Example, Let the twelfth Part be to be made for the Globe from the Pole to the Equator; find the Periphery of a great Circle for the given Diameter of the Globe by *Archimedes's*, or any other, Proportion. The Diameter being two Foot, the Length of two Foot marked on the Paper, and each Foot divided into ten Inches, and each Inch into

ten Parts, there will be two hundred Divisions; then As 7 is to 22, So is 200 to $628\frac{4}{7}$ or $61\frac{28}{100}$ Feet for the whole Periphery. And the fourth Part of it will be $157\frac{1}{7}$ hundred Parts, or $15\frac{7}{100}$ Feet, and the twelfth Part $52\frac{8}{11}$, or half a Foot, and $\frac{2}{100}$ and $\frac{8}{11}$ of $\frac{1}{100}$. Then draw a Line on Paper $52\frac{8}{11}$ hundred Parts long, taken from your divided Scale, in the middle of it, cut it with a Perpendicular $157\frac{1}{7}$ hundred Parts long, which will be a Quadrant, and the end of it is the Pole; and divide it into Degrees (the Length of one Degree will be had if $628\frac{4}{7}$ be divided by 360) then on the Pole, as a Center, describe Arches thro' each Degree, which will be Parallels; and with the Compasses take off on both Sides of the Meridians, $\frac{1}{4}$ of the Periphery (which will be known by the Proportion of the Parallel to the Equator, as in *Chap.* iv. at the end) and thro' each end draw Lines, and the inclosed Part cut off and applied to the Globe will cover $\frac{1}{2}$ of the Hemisphere. The Application will be easy; if the Part be the $\frac{1}{2}$ Part of the Earth's Superficies for the Difference between a strait, and curve Line in so small a Part, will not be sensible; and the Paper, being moistened, will stretch a little: and the Places are marked on the Papers before they are applied.

PROPOSITION VI.

To make Geographical Maps.

THE Problem is to be proposed thus, in a Mathematical Style, *Having the Situation of a Plane infinitely extended, to represent thereon the Places of the Earth, according to the Law of Perspective.* Or yet more generally thus:

HAVING a Point given on a Plane which represents some Place of the Earth, to find, on the same Plane,

Plane, other Points and Lines which may represent as commodiously and naturally the Places and Lines of the Earth, or their Situation to the given Place, and among themselves. Thus I think the Sense of the Problem may be better expressed.

BECAUSE few Students of Geography understand the Laws of Perspective, and can have no clear and distinct Knowledge of the Construction of Geographical Maps, nor judge of their goodness and badness, except they know the Elements of Perspective, according to which they are made; therefore a few things are to be here explained in that Art of Perspective.

THE Design of this Art, as every one knows, is to represent visible Objects on a Plane, whose Situation is known, *i. e.* that the Parts of the Picture may be so placed as to appear to our Eye the same way as the Parts of the Object would appear, if in the same Place. And the Method used for it is this :

WHEN they would represent a Point, Superficies, or Body, on a Plane, (whether they see it, or only conceive it) they first suppose it to be seen from some Point. Secondly, they conceive a Plane interposed between the Object and the Eye, in some certain Situation, thro' which, as a transparent Medium, the Objects are seen. Then, thirdly, they suppose Lines or Rays from every Point of the Object coming to the Eye thro' that transparent Plane; the several Points of that Plane thro' which the Rays come, being joined together with Lines, will represent the Appearance of the Object to the Eye in that Place; which yet (as any one may easily conceive) is not true in all Points according to the Laws of Optics. But because a better Method is not yet found, we must be satisfied with this: for Example, Let the Superficies of the Earth, and all the Points or Circles there-
on.

on, be to be represented; we first conceive the Eye situated in some Point without the Earth; and a Plane that is transparent interposed between the Eye and the Earth in any Situation: tho' it is better to suppose it perpendicular to the Line, from the Earth's Center to the Eye, that the Figure may appear the more regular. Then we are to conceive Lines drawn thro' that Plane, from every Point of the Earth, or of the Circles on it, as the Equator, Tropics, and from all the Cities, Rivers, &c. where these Lines go thro' the Plane you have the several Points representing them.

A N D because the Earth is round, it's Superficies cannot be all represented on one Plane; for two Places of the Earth would thus make two Points on the Plane, which would be confused; therefore the one half is to be represented in one Plane, and the other in another. And thus the Eye may be supposed to be within the Earth, as when we would represent one Hemisphere, the Eye may be supposed in the other, and the Plane between the Eye and the Hemisphere to be represented; and so it is if only one Place, as *Europe*, or *Africa*, were to be represented, when the Eye may be supposed in the Earth's Center.

F R O M this we think the Reader may understand the Nature of the Art of Perspective; but two things are to be explained, from which the Diversity of Geographical Maps arises.

W E said a Place must be supposed for the Eye; and since there are infinite Places in which the Eye may be, the Rays that come from the Object will penetrate the Plane in infinite Places; as a House, it's Walls and Frontispiece appear otherwise when the Eye is directly opposite to it, than when obliquely, and when the Eye is higher than it, than when lower: which Masters may show to their Scholars by a Figure. Thus the Earth and
the

the Circles on it will appear differently to an Eye above the Equator, and to another in it's Axis, or another above a certain Place between the Pole and Equator ; which will cause the Circles on the Earth to appear in different Figures ; which the Reader may easily conceive, especially if shown by a Master.

A N O T H E R thing which we think is to be conceived in this Method, is the Cause of the different bigness of Maps : for all Objects, as Churches or Houses, may be represented either as big or little on the Plane. The Cause of it is twofold ; 1. The further the Object is from the Eye, the Appearance is the smaller ; the Plane interposed continuing in the same Situation. 2. The nearer the Plane, on which the Representation is made, to the Eye, the Appearance is the less, and the nearer the Object, the greater (*a*).

A N D if the Eye be removed never so far from the Object, the Plane being fixed, provided the Eye be moved in a Line thro' the Center, or perpendicular to the Earth's Surface, the Figure will appear the same, tho' lesser (*b*) ; and so if the Plane be removed

(*a*) That is, if both the Plane and the Eye be together removed from the Object ; the Image becomes the smaller, the farther the Eye is removed. But if the Plane retains the same Situation, with respect to the Object, the Image becomes the larger, the farther the Eye is removed. For where the Eye touches the Plane, the whole Projection is confounded in one Point ; but as the Eye gradually recedes, the Projection enlarges ; and when the Eye is removed to an infinite Distance, the I-

mage becomes as large as the Object.

(*b*) In representing plain Surfaces, how far soever either the Plane, or the Eye be removed, the Figure of the Projection is no way altered, except in it's magnitude ; provided the Plane retains it's parallel Situation, and the Eye continues in the same perpendicular Line. And so, if a curve Surface is to be projected, and the Eye have a certain Situation, the Projection remains similar, tho' the Plane be removed to ever so great,
or

moved nearer to the Object, or from the Eye, the Image of it in these different Distances will be similar, if the Plane be kept still in a parallel Position tho' the Image will be different in it's Magnitude. But if the Table alter it's Position, or the Eye go out of the Line that passes thro' the Earth's Center, then the Image will be dissimilar; and the Rays will come thro' Points of the Plane that have a different Proportion in their Distances from another.

BUT in projecting all Bodies, and also that of the Superficies of the Earth, they use to place the Plane whereon the Picture is, so as to touch the Body or Superficies in a Point, thro' which, if a Line passes from the Eye, it would be perpendicular to the Body or go to the Earth's Center: but for the Magnitude of the Image we suppose the Eye to be more or less distant from the Earth, which will then appear small.

THESE things, of the Projection of the Earth and the Origin of Maps, being explained, in the general; we shall show the Method itself: where it may be asked, whether the Laws of Perspective must be kept to; the Design of the Maps being to represent clearly and conveniently the Places on the Earth in their due Distances; and whether this may be done without Optics: to which I answer that particular Maps may be made only by the Angles of Position, and the Distances of Places; but in large Maps there must be an exact Observation of the Laws of Perspective; even tho' the

or ever so small a Distance. But if the Eye be moved, tho' in the same perpendicular Line the Figure immediately alters, even tho' the Plane remains fixed. Hence there is a very different Appearance in the thirty fifth and thirty eighth Fi-

gures, proceeding solely from this, that in the former the Eye is supposed removed only a Semidiameter of the Earth from the Center; and in the latter, placed at an infinite Distance.

Places

Places of the Earth are not truly represented as they are on the Earth. For we must know, that there is a three-fold end for which Maps are made ;

1. That all Places may have such a Situation and Distance from the chief Circles of the Earth ; as the Equator, Parallels, Meridians, as on the Earth itself, that the Distance of the Parallel of each Place from the Equator, the Zone, the Climate, &c. may be seen in the Maps : for the Properties and Celestial Appearances in the Countries depend on it.
2. That the bigness of each Country may be in the same in Proportion as they are on the Earth.
3. That Places may be so situated, and distant from one another as they are on the Earth.

THE first of these should be exactly answered by the Maps ; and they do it for the most part ; being made from Tables of Latitude and Longitude : nor is it hindered by the Laws of Perspective. But the second cannot be accurately done if the Laws of Perspective be observed ; for the Parts of the curve Superficies that are furthest from the Eye, appear less than those on the Plane near the Eye ; yet the inequality is but small if the Eye be supposed to be at an infinite Distance from the Earth (c). The third Requisite ; no large

(c) It is a common and unavoidable Error in all the Projections of this kind, that the Parts unequally distant from the Center, are represented as unequally distant in the Map : whence the Magnitudes and Figures of the Parts of the Earth, are more or less altered, and distorted, according to the different Position of the Eye. To understand how this happens ; and how far it may

be corrected ; 'twill be proper to consider the Formation and Origin of these Representations. And this will be the easier, if we drop the Description of the Globe ; and make choice of any single Circle, by way of Example.

Suppose, therefore, half the Circle *CBCD*, were to be projected, *viz.* *CBC* ; (*Fig.* 34, 35, 36, 37.) the Eye being placed in *O*, in the Diameter

large Maps, such as those of the Earth, or the four Quarters thereof, can supply; tho' in small Parts they

meter BED, drawn out to any length towards D, and the Eye directed upon the right Line CEC; it appears that if any Difference be found in the Projections of the different Parts, it will be the greatest betwixt the Representations of the Parts in the middle of the Semi-circle, lying near B, directly under the Eye; and those which lie farthest removed from the former; viz. in Cc. These Parts, therefore, we are chiefly to consider.

Suppose then Bb to be an infinitely little Part of the Periphery; so as to pass for a right Line; and Cc, a Part equal to it; and the Eye at pleasure, situated in the right Line ED, infinitely produced: then the Representation of Bb, will be the little Line Ee, and the Representation of Cc, will be Cd.

Now, from the Elements of Geometry, because the Triangles O B b and O E e, are similar, $OB : OE :: Bb : Ee$. And again, because the Triangles O E d and c C d are similar, $OE : Ed :: cC : Cd$. Whence we may easily understand what the Proportion will be betwixt Ee and Cd, the Projections of the little Lines Bb and Cc at whatever Distance the Eye be placed.

For, first, if the Eye were removed from the Center E, (Fig. 34.) by the infinitely little Distance OE; then Ee will

be infinitely little in respect of Bb, or Cc, and therefore more than infinitely little with respect to the Line Cd; which in this Case is equal to half the Radius.

Secondly, if the Eye be in the Point D; (Fig. 35.) then Ee will be half the Line Cd: as in the first, second, and eighth Method of the Author, wherein the Parts directly exposed to the Eye, are represented much smaller than those placed at the Extremities of the Map. See Fig. 39, 40, and 45.

But if OD be the Side of a Decagon, inscribed in a Circle; the Projections of the Parts Bb, and Cc, will be equal to Ee, and Cd (Fig. 36.)

If the Eye (Fig. 37.) be removed to an infinite Distance, as in the Author's seventh Method; then Ee, will be infinitely bigger than Cd. And hence, in Fig. 43, the Projections of the Parts that fall in the middle of the Map, are much larger, than of those which approach to the exterior Circle.

When the Eye is placed in any intermediate Part betwixt those above-mentioned; the Lines Ee and Cd, will be proportionable to each other, in an intermediate Manner, respectively. So that we may make the Representations of the Parts Bb, and Cc, either equal, or in any Proportion, greater than each other, by chusing a proper, or corresponding Place for the Eye.

Among

they do it indifferently well, and most People think 'tis done in great Maps too; but we shall explain these things more fully in the Description itself; only we would here observe, that in all the general Maps commonly sold by Artificers, that Point is supposed to be just under the Eye in the Projection, which is in the middle of the Map; for

Among the infinite Positions assignable to the Eye, there are chiefly two that have been used, wherein it is placed either in the Point D, or removed to an infinite Distance; because no Method was found more easy in Description, or more commodious with respect to the Error abovementioned. And hence the Surface of the Earth has been represented in a very distorted and deformed Manner; whilst those Parts that fall chiefly in the middle, or extremities of the Map, were exhibited either much larger, or much smaller than they ought to have been.

This being observed by that excellent Astronomer, M. de la Hire *; he invented a Remedy for the Inconvenience, by making the Distance DO, (*Fig. 38.*) equal to FG, the right Sine of forty five Degrees. And hence the right Line OG, being drawn, bisecting the Quadrant BC, it also bisects the Radius EC, which represents that Quadrant; as easily appears by considering the similar Triangles OFG, and OEI. And thus the other Parts of the Quadrant

BC, and, in the like manner, of the whole Semicircle ABC, are represented in the Projection, nearly proportional to each other, and to Sense, perfectly so.

And as this Method of describing the Earth or Heavens, is not inferior to the former Methods, in Point of facility; so it is highly preferable in respect of accuracy and familiarity.

In this Projection, all the Circles passing thro' the Points B and D, and directly exposed to the Eye, are represented by right Lines; and all those which have their Planes parallel to the Plane of the Map AEC, or stand perpendicular to the Diameter BD also denote Circles in the Map; but the rest are elliptical; all which, whether strait Lines, or the Diameters of Circles, and Ellipses, are found in the same manner, as is described by the Author. We must however observe, that the Lines for dividing the Diameter AC, and BD, which in *Fig. 39* and *40*, are drawn from the ends of the Diameters, are to be drawn for the Points that lie removed from those ends by the interval of DO.

* *Hist. Acad. Scient.* 1701.

above that the Eye is supposed to be; and 'tis so in many particular Maps, but not all.

IT will be of use to understand what follows, if Masters and Scholars purchase sets of Maps; that what we say may be illustrated by Examples.

The first easy Method, in which the Eye is placed in the Axis.

1. I will show the Construction of the North Hemisphere this way. Let us suppose the Eye placed without the Hemisphere, and to be above the North Pole; and thus the Eye will be in the Earth's Axis, 'tis no matter whether in the Axis produced from the Pole, or in the Axis near the South Pole. For the Map or Plane on which the Representation is to be made, we may take the Plane of the Equator, or one touching at the North Pole, if the Eye be supposed to be in the Axis produced from the North Pole. But that we may the better express it without Confusion, let us suppose the Eye at the South Pole, and the Plane of the Equator to be the Map or Plane on which the Projection is to be made (the Earth being conceived to be small), and we are to suppose Rays from all Parts of the North Hemisphere coming to the Eye, which will all penetrate the Plane of the Equator; the Points where they penetrate will represent the Places they come from; and all the Points in the Circles, parallel to the Equator, will appear as a Circle, and therefore the Equator will be the primitive Circle and Bounds of the Projection; and the Pole will be in the Center, the Diameters will be the Meridians, and the Parallels of Latitude will have the same Center with the Equator, viz. the Pole: and each Place will be where it's Meridian cuts it's Parallel of Latitude. The other Circles or Semicircles will not be

be Circles in the Figure, but Ellipses; for Example, the Horizon and vertical Circles will be of an elliptical Figure, as made by a subcontrary Section of the Cone (as they who understand Conic Sections are sensible).

AND to understand this the better, we must conceive a Cone of Rays, whose Vertex, or Top, is the Eye, and the Base a Circle on the Earth to be represented; the Sides being the Rays from the Eye to the Periphery, and that this Cone is cut by a Plane several ways according to its Position; which will cause a Projection of the several Circles on the Earth. Thus the Ecliptic, only whose half is represented in the northern Hemisphere, makes an Ellipsis, or a part of it; yet properly it represents not the Ecliptic on the Earth which is changed every Day, but only the Ecliptic for one Day, or one Moment of a Day; and its Intersection with the Equator may be at any Point: yet in all Maps 'tis thought most commodious to be where the first Meridian cuts the Equator.

THUS we have explained the Origin and first Method of those Maps that suppose the Eye to be in the Axis; and how 'tis to be done we shall now show.

ON Paper, or a Plane: Let a Point be taken for the Pole, (*Fig. 39.*) and on it, as a Center, describe a Circle great or small, according as you would have the Projection, and that will be the Equator; these two are taken at Pleasure, but the rest must be found from these. Divide the Equator into three hundred and sixty Parts, and Lines drawn from the Center to these Parts will be Meridians; counting that the first which goes thro' *o o*. Then the Parallels of Latitude are to be described Let the four Quadrants of the Equator be marked *AB* from *o o* to 90, and *BC* from 90 to 180, and *CD* from 180 to 270, and *DA* from 270 to *o o* again; and taking one Quadrant, as *BC* from each

of whose Degrees draw occult Lines to D (and mark those that go thro' the 23 *degr.* 30 *min.* and 65 *degr.* 30 *min.*) the Line DB is as far from P as the Eye is from the Pole : and thro' P, as a Center, draw Circles thro' every Point of Intersection in the Line PC, which will be Parallels of Latitudes which may be counted on the Lines AP and CP 1, 2, 3, 4 from the Equator to the Pole ; and you will see the Latitude of each, and mark thereon the Tropic of *Cancer*, and the polar Circle at 23 *degr.* 30 *min.* and 66 *degr.* 30 *min.* there need only be coloured Lines at every fifth Meridian ; the rest being occult, that there may be room for affixing the Names of Places.

AFTER the Parallels and Meridians are drawn it will be easy to mark down the Places from the Tables of Latitude and Longitude ; finding first their Longitude, and then the Parallel of their Latitude ; and where these two cut one another is the Place.

IF the Ecliptic is also to be drawn, it must be done before the Names of Places are written ; and it being an Ellipsis in the Projection, the several Points are to be found thro' which it passeth ; the first Point is where the first Meridian cuts the Equator, *viz.* at the first of *Aries*, and the other Point in the opposite Part of the Equator, which will be the first of *Libra* ; and the intermediate Point is where the Meridian thro' ninety Degrees cuts the Tropic. Thus we have the three Points thro' which a Portion of the Ellipsis passes, which will be less than the half of an Ellipsis, for the other Points, as the first of *Taurus*, &c. there the Declination of these Points, and their right Ascensions from the first Meridian must be taken from the Tables here adjoined.

Declination.

Declination		Right Ascension.	
D.	D. M.	D. M.	
15 of <i>Aries</i> and <i>Virgo</i>	5 56	13 48	166 for 15th of <i>Virgo</i>
1 of <i>Taurus</i> and <i>Virgo</i>	11 31	27	152 1st of <i>Virgo</i> begins
15 of <i>Taurus</i> and <i>Leo</i>	16 24	42	137 for 15th of <i>Leo</i>
1 of <i>Gemini</i> and <i>Leo</i>	20 13	57	122 1st of <i>Leo</i> begins
15 of <i>Gemini</i> and <i>Cancer</i>	22 41	73	106 for 15th of <i>Cancer</i> .

THEN where 13 or 14 Degrees cuts the Parallel of 5 Degrees, or rather 6 Degrees, that Point will be the fifteenth of *Aries*; and where 27 cuts the Parallel of $11\frac{1}{2}$, there begins the first of *Taurus*; and where 42 cuts the Parallel of 16, there is the fifteenth of *Taurus*; and where the Meridian 106 cuts the Parallel 22 D. 41 M. there begins the fifteenth of *Cancer*; and where the Meridian 122 cuts the Parallel of 20, there the first of *Leo* begins; and so for the rest: these Points being joined by a curve Line, we shall have a Portion of the Ellipsis for the North Part of the Ecliptic, whose Signs are easily marked, taking the end of each Sign in the Tables to which you have it's Declination and Right Ascension, as we marked, 15 Degrees of *Taurus*; the first of *Cancer*, &c. Thus is the Map finished, that represents the northern Hemisphere.

'TIS plain from the Description and Construction, that the Method is easy and pleasant; now for the Use and Advantage thereof. We said there is a three-fold end in constructing Maps; the first of them is answered because the Latitude and Longitude of Places are thus shown accurately: it shows also the Zones, or the Distance of Places from the Sun's Way. As for the second, viz. the proportionate bigness of each Country; that is not so truly shown; for the nearer the Places are to the Equator, they are proportionably larger; yet the Difference is but small, because of the great Distance the Eye is supposed to be at from them; and that fault is com-

penfed by marking down the better the Places near the Equator, thofe near the Pole being not much inhabited. As for the third end, *viz.* the Situation of Places, and their Distance, this cannot be known by thefe Maps ; for the Lines on the Maps which denote thefe, are otherwife than they are on the Earth ; but to know the Situation of Places with refpect to any other, the Horizon of that Place muft be drawn, as an Ellipfis, thus. Let there be counted from the Meridian of the Place ninety Degrees both Ways, and the rifing and continuance of the Sun above the Horizon may be known from that part of the Map which begins and ends at the two Points where the Horizon cuts the Equator ; and the middle Point will be in the other Quadrant of the Meridian ; as far from the Equator as the Place is from the Pole : which will fhew the North Point. The South Point we fhall fhew how to find a little below, if more than a Hemisphere be fhown in the Map, it not being in an Hemisphere only, except the Horizon of the Pole, which is the Equator. Thus then we have three Points for the Horizon ; the other Points may be found eafier by the Globe, thus : Elevate it for the Latitude of the Place, and take the Point in each Parallel thro' which the firft Meridian paffes, and bring it to the Horizon, and mark the Degrees under the Meridian, and do fo for each Point in the firft Meridian, and then count the Degrees for each Parallel from the Meridian of the Place on the Equator both ways ; and where the Meridian cuts the Parallels anfwering them, you have the other Points thro' which the Horizon is to be drawn, by which you may judge nearly the Situation of other Places from the Place given.

THUS may almoft the whole Earth be drawn in one Map, if either Pole, for Inftance, the South Pole, be taken for the Place of the Eye : and the primitive

Circle

Circle inclosing the Map, may be any Parallel; for Example, if you take the antarctic Circle, if you would represent the Superficies between the North Pole and it in the Map, it wants only the lengthening out of the Meridian Lines in the former Construction, and Parallels drawn on the other Side of the Equator, and let the Ecliptic be drawn entire, and the Horizon if you please compleated.

BUT because the Parts, or Degrees, near the South Pole will be thus much larger than near the Equator, or in it, which is against the Truth of the Thing, 'tis better to divide the Map into two; one showing the North; the other the South Hemisphere.

THERE are few Maps drawn this way, tho' there are commonly two small ones of this kind added to the general right lined Maps, one representing the Countries about the North, the other about the South Pole; which Readers may see for the better understanding what is said here: but these things are better understood from seeing them done than by Words.

The second Method; the Eye being in the Plane of the Equator.

THE preceding Method of describing Geographical Maps, neither shows the Magnitude and Situation of Places, nor is it fit to describe an Hemisphere, with Poles in it, and so represent all Places in one Semicircle of the Meridian; and besides, 'tis not agreeable to our way of thinking, to have the Pole in the Center, which makes it more difficult to conceive the Map, and therefore another Method was found out; which is indeed more difficult than the former, but more fit to represent Places: and it also removes the Poles from the Equator.

TO understand this Method we must conceive the Earth's Surface divided into two Hemispheres, by an entire Circle of the first Meridian, and are to be exhibited in two Maps.

THE Eye is supposed in a Place of the Equator, ninety Degrees from the first Meridian; the Map in which it is represented is the Plane of the first Meridian; and the Hemisphere, which lies under that, in respect of the Eye above it, is that which we would represent on the Plane. In which Projection the Equator becomes a strait Line, and that Meridian ninety Degrees from the first, becomes also a strait Line, the other Meridians, and all the Parallels of Latitude, and the Ecliptic become Circles, because their Cones are cut by the Plane, or Map, in a subcontrary Section; the explication of which depends on the Doctrine of Conic Sections; and is understood better by Sight than by Words.

THE Description is made thus: Having taken in the Map the Point E (*Fig. 40*) for a Center, describe a large or small Circle ABCD, as you would have your Map large or small. This represents the first Meridian, and it's opposite; the Diameter BD represents the Meridian that is ninety Degrees from the first, and B the one Pole, and D the other; and AC perpendicular to AD is the Equator; Let each Quadrant AB, BC, CD, DA, be divided into ninety Degrees. And to represent the Meridians and Parallels, or to find the Arches of the Meridians and Parallels, this must be done.

1. LET the Equator AC be divided into one hundred and eighty Degrees, for it represents only the half of the Equator, or AE, EC in ninety Degrees each: from the Point D draw strait Lines to every Degree of the two Quadrants ABC, or apply a Ruler to D, and to each Degree in the Semicircle

micircle ABC, and it will divide it into one hundred and eighty Parts, which are Degrees of Longitude, to be marked 1, 2, 3, 4, from the first Meridian. Thro' each Point, and the two Pole Circles are to be described, which will be Meridians; but how a Circle is to be described thro' the three Points B_1D , or B_2D , &c. is to be learnt from Geometry: and that is by finding the Centers of each Circle, which will be all in the Equator, as the Meridian DAB hath E for it's Center. *Euclid* shows a Method, in *Book* iv. *Prop.* iii. by connecting the Lines B_1 , B_2 , &c. and bisecting them by Perpendiculars which will cut one another in the Equator, which, if need be, must be drawn out; but it will be easier in Practice, to draw Lines from B, thro' each Degree of the Semicircle, ABC to the Equator protracted, which will give the Points a , b , c , d , e , and so 1 a will be the Diameter of that Meridian, which should pass thro' 1; and 2 b , of that thro' 2, &c. if then 1 a , and 2 b , &c. be bisected, we shall have the Centers of the Meridians to be described.

YET the Work will be easier, and less liable to Error, especially in great Maps, by the Canon of Tangents; for thus there shall be no need of drawing Lines; for to divide EA, EC, &c. into Degrees we do thus: We divide, or suppose to be divided, EB, by a proper Scale, into ten thousand Parts, and from the Canon we take the Tangent of thirty Minutes, sixty Minutes, and one Degree and a half, &c. and each of those Tangents taken from the Scale, we lay down on EA, EC, EB, ED, and the nearest Points will contain one Degree to be counted as before. Then to find the Centers of each Meridian, take any Number between BC or E and any Degree, and the Double thereof take from ninety, or the Number itself from it's Complement; and taking the Tangent of the Remainder from the Canon, and set from E on

EC or EA, and it will give the Center of the Meridian to be described thro' that Degree, and so for all other Meridians. Practice will make this easy. The Foundation of the Work of finding the Centers is a Theorem in Trigonometry; *viz.* *The Difference of the Tangents of two Arches that constitute a Quadrant, is double to the Tangent of the Difference of the Arches.*

TO draw the Parallels; the Meridian DB is to be divided the same way, into one hundred and eighty Degrees, as EA, EC were; *viz.* by drawing from C to each Degree of the Periphery DAB, occult Lines; tho' the Parts of EA may be transferred to EB, the Points or Degrees from E to B, that is from the Equator to the Pole, or from E to D, the other Pole, are to be counted 1, 2, 3, 4, &c.

THEN thro' each of these Parts, and the corresponding Degrees on the Quadrants, are the Arches of the Parallels to be drawn on both Sides of the Equator. And thus we shall have the Tropics thro' twenty three Degrees thirty Minutes; and the polar Circles thro' sixty six Degrees thirty Minutes.

TO draw the Ecliptic there are two ways; for either the Ecliptic is supposed to cut the Equator in the Center, and then it will be a strait Line, and is to be divided the same way as the Equator; but if it be drawn so as that the Point of Intersection, or the first of *Aries*, shall be in the first Meridian; then it will be the Part of a Circle, of which the two Points will be A and C, and the third the Point where the Meridian of ninety cuts the Tropics: and thus 'tis commonly drawn, because thus 'tis always in both Hemispheres.

AND to determine the Places in those Maps, their Latitudes and Longitudes are to be taken out of Tables; and where their Meridian cuts their Parallel, this is their Place.

BY the like Method the whole Superficies of the Earth may be drawn in one Map, if we take not the Planes of a Meridian for the Map; but another that shall be parallel to it, and very near the Eye: and thus the whole Parallels, and the Meridian with it's opposite, may be drawn. But yet the Appearance will differ much from the thing itself on the Earth; and therefore is not practised by Artificers, who rather draw two Hemispheres in one Map; yet it will be useful for Students to exercise themselves in such Things: and it will be best to place the Eye in the first Meridian at A; thus BD will be the first; and the Equator will not be AC, but a Line parallel to it, thro' a Point in ED, which is divided into as many Degrees as there are in the Arch cut off.

A second Advantage is, that it aptly represents the Hemisphere between the two Poles.

A third is, that it nearly shows the Latitudes and Longitudes of each Place; as they are on the Earth.

THE Disadvantages are first, that the Degrees of the Equator are divided unequally; being larger the nearer to the first Meridian, or it's opposite; and therefore the Countries that are equal on the Earth will appear here unequal, as in the preceding Method; but this defect is in part remedied if the Eye be supposed far from the Earth: and the same way do the Places about the Poles seem larger than they should do. 2. The Situation of Places is not easily found, nor the Distance of two Places.

The third, fourth, and fifth Method for right-lined Maps.

T H E R E are to be fold universal Geographical Maps, that have all strait Lines, both for the Parallels and Meridians; which is impossible by the Law of Perspective: nor is it possible that the Eye and the Plane can be so situated that both the Parallels and Meridians will appear as strait Lines. In the first Method the Meridians were strait Lines according to Perspective; and the Parallels are Circles: and in the fifth Method following, the Circles of Latitude will be strait Lines, and the Meridians Ellipses. In other Methods, by the Law of Perspective, both are curve Lines, excepting one wherein the Meridians are strait Lines; but the Circles of Latitude are Hyperbola's, that is when the Eye is placed in the Centre of the Earth, and seeth the Hemisphere on both Sides of the first Meridian, and the Plane thro' which the Eye looks, is parallel to the first Meridian; thus the Meridians will be strait Lines, and the Circles of Latitude Hyperbola's. The Division of the Equator and Meridians according to this Method being easy, they that delight in a Variety of such things may draw such a Map, tho' the Hyperbola's will not be so easily drawn as the other Parts; therefore we shall say no more of it: they who would try it may consult a Master. The right lined Maps then are not according to the Laws of Perspective, but rather against them: and they are of two Sorts, some have both the Degrees of Latitude and Longitude equal, as they were of old; others now have the Degrees of the Equator equal (contrary to the Law of Perspective) but not of the Meridians: for the Degrees on them become still bigger the nearer either Pole; so that the eighth Degree is ten Times larger

larger than the first at the Equator (and at the Pole they are infinite which cannot be expressed in any Map); whereas the Law of Perspective admits only of a threefold encrease there (*d*).

THE right-lined Maps, according to the first Way are very easy; for having taken *AB* (*Fig. 41.*) for the Length of the Map, 'tis divided into one hundred and eighty Degrees, or equal Parts, for one Hemisphere; and thro' each Degree are drawn Meridians, strait and perpendicular; and on these are taken Parts equal to those on the Equator; and thro' each Degree of Latitude are drawn Parallels to the Equator, or Circles of Latitude; and thus may each Place be marked, as before, by it's Latitude and Longitude.

THE second Method agrees with the first in the equal Divisions of the Equator, thro' which Perpendiculars are drawn, which will be Circles of Longitude; (*Fig. 42.*) but for drawing Parallels to the Equator, there is another Method: for the Meridians have the Degrees on them greater, nearer the Pole. And this happens because other Maps do not show the Distance, nor position of two Places, both which may be had here: for because the Meridians of each Degree are equidistant, or parallel, therefore the Places are thereby removed from the first Meridian, more than they ought to be; and the more the nearer the Pole, in proportion as the whole Sine exceeds the Sine of the Complement of the Latitude of the Place; for As Radius to the Sine-Complement of the Latitude of

(*d*) The Laws of Perspective do not indeed regard the Increases of the Meridians, in this kind of Maps, but observe a different Proportion, as the Makers of these Maps allow. But that the Degrees should increase so

largely near the Pole, is not contrary to the Laws of Perspective; which affords not only a tripple, but any other Degree of Increase, as appears from the Note immediately preceding.

the

the Place, So is a Degree on the Equator, or any Number of them, to the same Number on the Parallel; and therefore they must be less there than on the Equator, and the less the nearer the Pole: but in right-lined Maps they are drawn equal in all the Parallels. And as Degrees on the Circles of Latitude encrease more than they should, those of the Meridians are made to encrease as much; that the one may correct the other; for as the quantity of one Degree in each Parallel is to a Degree on the Equator, so is the Sine-Complement of the Latitude of that Parallel where the Degree begins to the whole Sine: and so is a Degree of Latitude on the Equator to a Degree of Latitude through whose beginning the Parallel passeth. But more accurately thus: by taking the Sine-Complement of the Latitude which begins the Degree, and adding it to the Sine of the Complement of Latitude that ends the Degree; and taking the one half of both for the first Term in the Proportion.

For Example.

LET the quantity of the first Degree of Latitude be to be determined, the Degree on the Equator being ten Parts; by the first Proportion it will be equal to that on the Equator, because the Degree begins at the Equator; but by the second Proportion I take the Sine-Complement of 0 Degrees (which is the Sine of 90) 100000, which I add to the Sine-Complement of 1 Degree, or the Sine of 89 Degrees, which is 99985, and they make 199985, whose half is 99992; then As 99992 is to 100000, So is 10 to $\frac{80}{100000}$; for the first Degree which increases so little above 1 Degree on the Equator, that it cannot be marked on the Map; so we may count them equal: but they increase sensibly as they approach to the Poles. Let
the

the 60 Degree be to be marked by the first Proportion, the Sine-Complement of 59 is 51503; then As 51503 is to 100000, So is 10 to $19\frac{2}{3}$ to be taken from the same Scale where the Degree is made ten Parts. By the second Proportion the Sine-Complement of 59 is 51503, and the Sine-Complement of 60 is 50000, their Sum 50751; then As 50751 is to 100000, So is 10 to $19\frac{2}{3}$; which is but a little above the former, and not worth the Pains to observe; and when the bigness of the second Degree is found, 'tis thus to be added to the first; and the quantity of the third Degree is to be added to them. To make the Thing more easy, we here add a Table of the Magnitude of each Degree; the Degree on the Equator being 100.

<i>End of Degr.</i>		<i>End of Degr.</i>		<i>End of Degr.</i>	
1	100	17	1725	33	3499
2	200	18	1830	34	3619
3	300	19	1936	35	3740
4	400 $\frac{1}{3}$	20	2042	36	3863
5	500 $\frac{2}{3}$	21	2150	37	3988
6	601	22	2256	38	4114
7	702	23	2364	39	4241
8	802	24	2473	40	4371
9	903	25	2583	41	4502
10	1005	26	2694	42	4636
11	1107	27	2806	43	4772
12	1209	28	2918	44	4909
13	1311	29	3032	45	5053
14	1414	30	3147	46	5193
15	1517	31	3263	47	5338
16	1621	32	3347	48	5486

<i>End of Degr.</i>	<i>End of Degr.</i>	<i>End of Degr.</i>
49 5637	61 7749	73 10900
50 5791	62 7960	74 11243
51 5981	63 8175	75 11617
52 6109	64 8399	76 12017
53 6274	65 8631	77 12445
54 6441	66 8872	78 12908
55 6611	67 9023	79 13409
56 6790	68 9384	80 13960
57 6970	69 9691	81 14565
58 7157	70 9943	82 15243
59 7349	71 10243	83 16009
60 7546	72 10558	

THE Degrees of Latitude being thus marked on the Meridian, draw Parallels thro' the end of each Degree; and each Place is to be marked where it's Circle of Latitude and Longitude intersect each other.

BUT the Countries near the Pole are stretched too much northwards; and therefore the Places between the Pole and the polar Circles used to be set down in two Maps, by the first Method and joined to the universal Map.

THE Use of such Maps is, (1.) to find the Latitude and Longitude of Places, as before. (2.) Having, in *Fig. 42*, the Place R, from which I sail, and the Place S, to which; to find the Point I must steer my Course to; I draw a Parallel thro' R, which, with R S, shows the Angle or Point I must steer to. Seamen use another way. (3.) The Distance between two Places may be found, if I take their Distance with the Compasses, and set it on the Meridian, so as the Feet of the Compasses may be equally distant from the Parallel in the middle

middle between these two Places : but this is not very accurate.

The sixth and seventh Methods.

PTOLEMY, in the latter Part of the last Chapter of his first Book of Geography, proposes another Method, and shows how to represent thereby the then known Part of the Earth. In this Method both the Equator and Circles of Latitude are also Arches of Circles; and the Meridians, Arches of an Ellipsis. The Eye is supposed to be above the Meridian, which is in the middle of the Earth inhabited, and in the middle between the greatest and least Latitude known; but because of the trouble of drawing an Ellipsis, and because it seems to be designed by *Ptolemy* to represent the Part of the Earth inhabited, 'tis not used by Artificers. And the Method of representing the Circles of Latitude by strait Lines, but the Meridians as halves of Ellipses, is something like this; which Projection is made by supposing strait Lines to fall perpendicularly from every Point of one Hemisphere, on the Plane of the first Meridian Circle; and the Eye at an infinite Distance: as those skilled in *Dialling* say, that all the Rays from the Sun, or any Part of it, come so near *Parallels* as to be accounted such, and cause the same Shadow as if they were parallel: which is not very difficult to conceive.

IF therefore you would represent an Hemisphere of the Earth after this manner, chuse a Point on the Plane as *E*, (*Fig. 43.*) and from that, as a Center, describe a Periphery *A B C D*, the Quadrants being *AB*, *BC*, *CD*, *DA*, divide each into ninety Degrees, beginning from *A C* to *B* and *D*, and *B A D* will be the first Meridian, *B C D* it's opposite, and the middle one *B D* will
be

be ninety Degrees from the first B A D. Then draw A C, which will be half of the Equator, and draw Parallels thro' every Degree of the Quadrants, in which you will have the Tropics at twenty three Degrees thirty Minutes, and the polar Circles at sixty six Degrees thirty Minutes. The Parts into which E B, E D are divided, are Degrees of the Meridian B D, which are to be marked 1, 2, 3, &c. and the same Parts must be taken in the Quadrant of the Equator E A, and the other E C, and marked 1, 2, 3, to 180, beginning at the first Meridian B A D. And thus the Parts in E A, E C will have the Parts into which the Equator is divided, and are Degrees of Longitude, thro' which, and the Poles, Meridians are to be drawn as half Ellipses; and because B D is the longest Diameter, and the shortest is different in each Ellipsis, and will be between E and the Degree of Longitude; it will be easy to draw them with an Instrument now common, having their longest and shortest Diameter. The several Points in the Ellipsis may be found, which may be joined by a good Hand; but 'tis better to draw them with a thin Piece of Whalebone or Steel.

HAVING thus drawn the Circles of Latitude, and the Meridians, all Places may be laid down according to the Points in which their Circles of Latitude and their Meridians intersect. In which Map the Ecliptic will be either a strait Line, or a curve (as was shown in the Maps by the second Method) and may be easily drawn.

THESE kind of Maps are as good as the former; and have this Advantage, that they represent plainly the decreasing of the Circles of Latitude towards the Poles.

IF the Division H G and H K (*Fig. 44.*) be not thro' the Lines drawn, on Account of the great Distance of the Eye D, it will be easy by Calculation

Calculation to find the Parts for every Degree thus:

AS the Distance of the Eye, taken from the Center of the Earth, with the Sine of the Complement of the Arch of the Equator to be represented, is to the Sine of the same Arch; So is the Distance of the Eye from the Map, to the Part of the Line HG or AK, which will represent so much of the Equator.

For Example. Let us suppose the Eye D to be removed from the Center of the Earth two hundred of it's Semidiameters, and the Map HK one hundred. Then DE will be 200, and DH 100 of such Parts as EB or EA is 1. Let us first find the Longitude of GHK, which is to represent a Semicircle of the Equator at this Distance of the Eye and Map, it will be then,

As DE is to DH, So is EA to HG, or the Semidiameter of the Earth; or as $200 : 100 :: 1$ to $\frac{1}{2}$; which shows, that GH or GK is to be half of the Length of the Semidiameter of the Earth: which indeed is too great, and can be represented on no Plane.

THEREFORE, for the Earth we conceive a small Sphere, whose Diameter is two Feet; then HG or HK will be one Foot, on the former Supposition.

YET if you would know how much the Eye must be removed from the Earth, that the Semidiameter of the Equator EA may make the Projection HG of a given Length, as one Foot (the Semidiameter of the Earth being 19598300) it may be found by this Proportion; supposing the Distance of the Map from the Eye HD to be 100000. As HG is to DH, So is EA to DF, *i.e.* $1 : 100000 :: 19598300 : 1959830000000$, of which 18000 make a *Dutch* Mile; which is a great Distance.

BUT in Practice we do not take the Earth itself, but it's Type, or a little Sphere, from which we need not suppose the Eye to be so far ; which will make no Error in the Projection.

The eighth Method ; in which any Place may be made the Center of the Map.

IF you would have a Map in which the Situation of all places with respect to some one place, or any other, as also their Distances to be seen and found ; there is a Method by which the Superficies of the Earth is so represented that any place may be made the Center of the Map, and other places lie about it, which Maps please those that erroneously think their Country is in the middle of the Earth, as the *Chinese* do, and the *Jews* did of old.

TO describe such a Map : Let us choose to have *Amsterdam* in the Center ; it's Latitude being fifty two, and the Eye placed in the Point opposite to the Zenith, that is the Nadir. The Map will be the Plane of the Horizon, or some Parallel to it, if you would represent more than an Hemisphere ; which may be better done in this Map.

LET then E (*Fig. 45.*) be taken on the Plane for *Amsterdam*, and having drawn the Periphery for the Horizon, divide it into four Quadrants, and each of those into ninety Degrees, BD being the Meridian of the place, B the North Point, and D the South. The Diameter AC, the East and West Line, is the Prime vertical, A the West, and C the East, which is ninety Degrees from the place. And all the vertical Circles are represented by strait Lines from the Center E to each Point on the Horizon ; but 'tis better to omit some of them ; you may put a Pin in the Center, and turn
2 a Ruler

a Ruler on it which will serve to draw the Verticals.

THEN divide BD into one hundred and eighty Degrees, as before; drawing from A to each Degree in the Semicircle BCD; the Point in EB, which is fifty two Degrees on the Arc BC, is the North Pole; which mark with the Letter P, and the Point ED which represents fifty two Degrees (counting from C to D) will be the Point where the Equator intersects the Meridian of *Amsterdam*, mark it with Q, and count from it to P the Degrees 1, 2, 3, &c.

AND likewise from Q to D, and from B to P, count 38, 39, 40, &c. Then taking a Point of equal Degrees from P, as 99 and 99, or 88 and 88, &c. making that Interval a Diameter, draw the Circle which will be a Circle of Latitude for each Degree; and the Tropics and polar Circles with the Equator.

FOR the Meridians; first draw a Circle thro' A, P, C, which will be a Meridian ninety Degrees from that of *Amsterdam*; the Center of it is M, in BD, drawn to the Point N, the South Pole; PN being a Diameter, draw thro' M, FH parallel to AC, extending it to K and L. And divide the Circle PHNF into three hundred and sixty Degrees, and by the help of a Ruler, applied to P, and each Degree, divide the Line KFHL, which will give so many Points; thro' which and the two Poles the Meridians are to be drawn. The Centers of these Arches are also in the Line KL, and are found as by the former Division of it; but the Meridians between A and E have their Centers between M and L.

HAVING thus described Circles of Latitude and the Meridians, 'tis easy to mark down the places on the Earth, whose Situation from *Amsterdam* is readily seen. And the same Division of EB, should

be on the Ruler, which being laid on E, the place shows their Distance in Degrees, and in what Point they lie. How this Map may be made by the Globe, we shall show in the fourth Method of making particular Maps.

The first Method of making particular Geographical Maps.

WE have said enough to the Description of universal Geographical Maps; we shall next show how particular Maps are to be made. Maps are made of the great Places, as *Europe, Asia, Africa, America*, or small Places: if the former, the foregoing Method for general Maps may be used; tho' different Methods are to be employed for different places. *Africa* and *America* having the Equator passing thro' them, are not easily drawn by the first Method, but properly by the second; the Eye being placed in the Plane of the Equator, above the Meridian in the middle between their East and West Bounds. And therefore the Equator is a strait Line, and the Parallels, and the Meridians will be Arches of Circles; but the first and sixth Method are best to draw *Asia* and *Europe*: and the first Method is best as we said to draw the *Frigid Zones* at the Poles.

FIRST of all a strait Line is to be drawn for the Meridian of the Place over which the Eye is supposed to be; and to be divided into Degrees, according to the Method before explained; which will be degrees of Latitude: and they are to be marked 1, 2, 3, &c. Then from the Tables the most southerly and northerly places of the Country are to be limited by two Parallels of Latitude; and these are to be cut by perpendicular Meridians thro' which Parallels of Latitude pass, also

at right Angles ; and so each place is marked by it's Latitude and Longitude.

The second Method of drawing particular Maps.

BUT Artificers use another Method in drawing small, or not very large Maps. First there is a Line drawn a-crofs the Page, and at the lower end, for the Parallels of the place most southerly ; and on it are taken equal Parts, according to the Degree of Longitude the Country extends to ; then a Line is raised perpendicular on it's middle, divided into as many Parts as the Degrees of Latitude from the North to the South Part : the bigness of those Parts is known from the Proportion of the Degree in that Parallel they are in hath to the Degree on the Equator. And another Line, parallel to that at the bottom, is drawn at the top, divided into as many equal Parts, as the lower Line ; and Perpendiculars are drawn from the Divisions below, to those above, supposing the Latitude of that above ; and that below, not much different, or not much distant from the Equator.

BUT if the Distance from the Equator be great, or the two Latitudes much different, the Parts above and below must not be equal. But they must be in proportion, as a Degree in the Parallel above, is to one in the Parallel below ; which Proportion may be known by the Table laid down in *Chap. iv.* And thus having the Meridians and Parallels, you may set down each place, as before.

The third Method of describing particular Maps.

IN representing Provinces of small Bounds, we use another Method for the most Part, which

was explained before ; for shewing the Situation of places, and their Distance more accurately.

THE Method is this : There must be found by mathematical Instruments, the Angle of the Position of one place from another ; which is to be transferred to Paper. For Example ; Let there be five places of a Country to be laid down, according to their Situation and Distance, which we call A, B, C, D, E. (*Fig. 46.*) And let us choose one, as A, from which the rest, or most of them, may be seen ; and with an Instrument observe how they lie from you, or from the Meridian in which you are. Then taking, on the Paper, a Point as A, describe a Circle on it (which yet may be omitted if you have a Protractor) and take one Diameter of the Circle for the Meridian of A, as H A K ; the other perpendicular to it, as H A K, will show the East and West Point ; F being the North, and G the South. Suppose then that A looked from B thirty Degrees between South and East ; count so many Degrees on G H, and draw a Line thro' the thirtieth Degree : this shows how B lies from A ; and thus the Points the places D and E lie in are to be set down. Then going to one of the other places, whose Distance is known from A, with an Instrument observe the other three places C, D, E. This being done ; Let there be drawn on the Paper a Scale of Miles, great or small, as you would have your Map ; and on the Line between B and A, set down their Distance known ; which will give the place B ; and thro' B draw another Meridian, parallel to the former ; and making a Circle about B, as about A, draw from it Lines showing the Points that C, D, and E lie in ; and where these Lines cut the Lines from A, will be the Places of C, D, E. And the same is to be done, if there had been more places.

The fourth Method; by the Globe.

WE may, with the help of the terrestrial Globe, represent Places remote from one another, and know their Situations and Distances: yea the whole Superficies of the Earth may be thus laid down; so that the given place, or any place be in the middle of the Map, as in the sixth general Method; so that this Method may be brought in among those for general Maps: but 'tis better not to extend the Map beyond an Hemisphere. For Example; Let it be proposed to set down all the Places about *Amsterdam*, in their due Situation and Distance. First choose a Point in the Middle, as A, (*Fig. 46.*) and describe a Circle about it; and let FG be the Meridian Line, and HK the East and West; divide each Quadrant into ninety Degrees.

THEN, on the Globe, bring *Amsterdam* to the Meridian, and elevate the Pole for it's Latitude, fix the Quadrant of Altitude at the Zenith, and bring it about to every Place you would have set down; as to the Bounds of *Spain*, *France*, &c. and observe in each the Angle made by the Meridian, and the Quadrant, *i. e.* the Angle of Position, with the Meridian of *Amsterdam*; and also the Degrees on the Quadrant between *Amsterdam* and each place; then draw on your Paper Lines from A, according as their bearing is between the four Cardinal places (we shall show afterwards how the Trouble of drawing Lines may be spared); on these Lines are to be set down their Distances by the Quadrant from a Scale, large or small, as you would have your Map; and you will thus have the several places.

BUT if the Map is to be large, and the Places at a great Distance, the Line may be divided by the Laws of Perspective; by supposing the Eye at

the Antipodes of *Amsterdam*; and for the Map, we take the Plane of the Horizon for representing an Hemisphere; but if a greater or lesser Part of it, then we take a Plane for the Map, that shall be parallel to that of the Horizon, which is to be distant from it the farther, as what we would lay down is above an Hemisphere. Draw then in another Paper a Circle, whose Center is M, and N O a Diameter, and P Q another, perpendicular; divide N Q into ninety Degrees, and take below Q Degrees in proportion to the excess of what you would represent above an Hemisphere, and thro' R draw a Line to M O parallel to Q M, and from O draw Lines to each Degree of the Quadrant N Q or N Q R, if a greater Portion than N Q; which will divide M Q or S R, into Parts which will be Degrees: then choose a Line of such a Length as we would have to represent the furthest Distance from *Amsterdam*, which will be about half the Breadth of the Map; that Line is to be divided as M Q or S R, and mark the Parts 1, 2, 3, 4, &c. from that, as a Scale, take the several Distances, and set them on the Lines that go to the places; and you have the Map finished. But the Lines need not be drawn to the places; if you have a Scale, or Ruler, divided as M Q or S R; apply one end to A, and the Scale on the Ruler being brought to Points that show the bearing of the places, you may set off their Distance, counting from A, on the Ruler.

The fifth Method; for Sea-Charts.

S E A-Charts are strait lined, and have the Meridians all parallel; otherwise than was shown in the last Part of the second Method.

T H E Y are two-fold; the Degrees on the Meridians being either equal or not: they are made
the

the same way as in the fourth and fifth Method of general Maps, only they represent but little, and have more Sea-Compasses on them for finding the Bearings. We shall show their Use hereafter, for sailing. The Degrees on the Meridians are nearly equal when a small Part only is exhibited; as the Mediterranean: and if the Latitude be great, or the North and South Parts of the Country far distant then they are made unequal.





C H A P. XXXIII.

Of the Distance of Places.

P R O P O S I T I O N I.

Having two Points, or Places, on the Globe, to draw from the one to the other an Arc, which shall be the Part of a great Circle on that Globe.

CONCEIVE a right Line drawn from the one Point to the other; and from both, two Lines to the Center; these three make a Triangle; which if extended, will cut the Superficies of the Globe, and the Section will be the Periphery of a great Circle; and the Arch between the two Places will be what is wanted. Or take with your Compasses a Quadrant of a great Circle, and fixing one Foot at each Place, describe two Arches cutting one another; where they intersect will be the Center of a great Circle, that will pass thro' the two Points given.

P R O P O S I T I O N II.

The shortest Distance between two Places on the Superficies of the Earth, is only one Line, (excepting the Places of the Antipodes) which is the Arch of a great Circle, intercepted between the two Places.

THE shortest Distance between two Places, is a strait Line from the one Point to the other; as appears by the Definition of *Archimedes*; and is easily deduced from other Definitions: and therefore the shortest Distance between two Places on the Surface of the Earth, is a strait Line conceived to be drawn from the one Place to the other; but the Superficies of the Earth, being a convex Curve, hence it is that the strait Line, which is truly the shortest Distance of the two Places, falls within the Cavity of that Superficies; but we consider only those Distances which are on the Superficies; and therefore we added in the Proposition *on the Superficies of the Earth*. Among the several Ways, the shortest of all is the Arch of a great Circle interposed between two Points, drawn as we shewed in the preceding Proposition; and that this intercepted Arch is the shortest of all, appears from this geometrical Theorem. *If the Arches of two unequal Peripheries be taken, whose Chords or Subtenses are the same, the Arch of the greater Periphery, will be less than that of the lesser*: for all circular curve Lines, passing through two Points, are parts of smaller Circles, excepting that Arch which is part of a greater Circle; and that this Arch is less than other Curves not circular, (as solid Lines, or the Helix) of which infinite Number may be supposed drawn on the Superficies of the Earth, is shown by others: which Theorem belongs not to Geography, but Geometry; which also shows, that only one Arch of a great Circle can be drawn from one Place to another.

PROPOSITION III.

The Distance of Places change not.

THE way of travelling from one Place to another may indeed change, but the shortest Distance is always the same; except the Surface of the Earth should break asunder: but by Places here, we understand immoveable Points. If indeed the Superficies between two Places rises higher, the Distance is greater; if it fall lower, 'tis shorter.

PROPOSITION IV.

No Place is distant from another, more than two thousand seven hundred German Miles; of which fifteen make a Degree.

FOR the Earth's Superficies being spherical, there cannot come in between two Points, an Arch greater than an hundred and eighty Degrees, which is a Semicircle. But an hundred and eighty makes two thousand seven hundred German Miles; one Degree being fifteen.

PROPOSITION V.

The Distance of the Antipodes, is two thousand seven hundred German Miles, or an hundred and eighty Degrees.

1. THE shortest Distance from the Antipodes is not one Line, but an infinite Number all equal; tho' properly speaking, they cannot be called the shortest Distances, but such as there is no shorter.

2. THE circular Distances between the Antipodes, are all Parts of greater Circles, and not of lesser,

leffer, (as those between Places which are not diametrically opposite) and they are infinite.

3. A great Circle passing thro' two Places passes also thro' the Antipodes of those two Places.

4. THE Distances of a Place from two Places that are Antipodes to those two Places, make one hundred and eighty Degrees; and the Distance from the one being known, the Distance from the other is also known.

5. THESE five Propositions are so plain, that any one who considers them, will understand them.

PROPOSITION VI.

A Place on the Surface of the Globe being given, to find all those Places that have the same Distance from it; but the Distance must not be more than two thousand seven hundred German Miles.

ELEVATE the Globe for the Latitude of the Place, bring it to the Meridian, fix the Quadrant of Altitude at the Zenith, count on it the Degrees of Distance, and mark with Chalk where they end; then turn the Index round, and the Chalk will go over all those Places that are at the given Distance: or take with your Compasses the Degrees of Distance from the Equator, and fixing one Foot at the given Place, turn the other about, over all the same Places sought; and if the Distance be greater than ninety Degrees, take it's Supplement to one hundred and eighty, and fixing one Foot at the Antipodes of the Place, revolve the other. And if you would use the Quadrant, bring the Antipodes to the Zenith; and fixing the Quadrant there, turn it round: and where the Supplement of the Distance ends, you will have the Places sought under it in a Circle.

PROPOSITION VII.

Whence it is that the Distance in Journeys is greater than the shortest, or geographical, Distance.

1. FROM Woods that lie between, and are impassable. 2. High Mountains, and deep Valleys. 3. Bogs, Lakes, and in general the Waters we meet with in travelling by Land. 4. In Sea Voyages there are Lands that run out into the Sea, and Islands that hinder a strait Passage. 5. A peculiar flowing of the Seas. 6. The Winds.

BUT some may ask, are there not Land Journeys shorter than Geographical, or the shortest, Distance. To which I answer, tho' the Earth's Figure is spherical, so far as can be discerned; yet in the first Book we showed it was not Geometrically so altogether; but raised and depressed unequally in several Places: and if there be two Places that are distant from the Earth's Center, eight hundred and sixty Miles, and the Space between them depressed, then the Land-Journey, *cæteris paribus*, will be shorter than the Geographical Distance; as the Chord is lesser than the Arch.

PROPOSITION VIII.

To find the Distance of two Places on the Globe, or on the Maps made for particular Places.

BRING one of the Places to the Zenith, and fix the Quadrant there, and turn it 'till it come to the other; then count the Degrees between them, and turn them to Miles, or take their Distance with the Compasses, and see how many Degrees it makes on the Equator; but if the Distance be
greater

greater than ninety Degrees, you must, as in *Prop. vi*, take the Supplement to one hundred and eighty, or it's Distance from the Antipodes, by bringing their Place to the Zenith, and applying the Quadrant there; and that Distance in Degrees, taken from one hundred and eighty, gives the other Distance above ninety Degrees.

THIS Distance is not exactly found in universal Maps, but in particular Maps there uses to be a Scale of Miles added; and taking the Distance with the Compasses, and applying it to that Scale you have the Miles, or Leagues, contained in it.

BUT this Method will not hold if it be a Map of a large Place; for no Map can be made that will show truly all Distances: tho' a Map may be made to show the Distance of one Place, from all other Places, as we saw in the Construction of Maps.

PROPOSITION IX.

Having the Latitude and Longitude of two Places to find their Distance.

THE Solution of this by the Globe is easy, or by an universal Planisphere; but difficult, tho' accurate, by spherical Trigonometry.

ON the Globe thus: Take any Meridian at pleasure; 'tis better to take the Meridian of one of the Places if it be drawn; or, which is more commodious, take the first Meridian, and count from it on the Equator the Difference of the Longitude of the two Places; and where that Number ends, must be brought under the brass Meridian, and the Latitude of both Places marked on their Meridians; and taking the Distance of the two Marks, with the Compasses, apply it to the Equator; and you have the Distance in Degrees: if it be
more

more than ninety, you must take a Thread well stretched, and apply it.

BECAUSE a Planisphere is fitter for use, especially to Sailors, that have frequent occasion for this Problem, and love to use that Instrument, we shall here explain the Method.

THERE are two Cases in the Problem; either first, the Places have the same Longitude; or have one hundred and eighty Degrees of Difference in Longitude; and then you need only turn the Difference of Latitude, or the Degrees of Distance on the Meridian to Miles: and if the one Latitude be North, the other South, you must add their Latitude; which is easily done by taking the Degrees between the two Places.

BUT if the Places are in different Meridians, and out of the Equator you must do otherwise.

AND it will first be useful to show the Cases in which the Solution varies: and that will make it very easy; as will appear by Examples, in which Students should exercise themselves.

1. IF the Places have the same Longitude, and have Latitudes of the same Kind; then the Difference of Latitudes in Degrees may be turned to any other Measure.

2. IF they have the same Longitude, and their Latitudes of different Kinds, the one North, the other South; then add the Latitudes, and you have the Distance in Degrees.

3. IF the Difference of Longitudes be one hundred and eighty Degrees, and they have different Latitudes, take the Difference of Latitude, and subtract it from one hundred and eighty Degrees; what remains will be the Distance in Degrees.

4. IF the Difference of Longitude be one hundred and eighty Degrees, and they have the same kind of Latitude; add the Complement of their Latitude, and you have the Distance in Degrees.

5. IF

5. IF both Places are in the Equator, then the Difference of Longitude in Degrees is the Distance.

6. IF both Places have the same Latitude, and not more than twenty Degrees, and the Difference of Longitude be small, enter with that Latitude the Table for the Parallels bigness, in *Chap. iv*, and take out the Quantity of one Degree in that Parallel; then take the Difference of Longitude, and multiply it by the Miles in one Degree.

7. IF both Latitude and Longitude differ, or if the Latitudes be the same, but above twenty Degrees; and the Difference of Longitude great; which often occurs; we must not follow the former short Methods, but be at more Pains; and for this chiefly is the Problem proposed.

WE have given a Solution by the Globe; and by the Planisphere it may be done thus: Bring the Rule of the Planisphere to the Latitude of the Place; then count the Difference of Longitudes in the Meridians, beginning at the other Part; and where the Meridian, that terminates that Number, cuts the Parallel of the other Latitude, place there the end of the Index; then apply the Rule to the Equator; and the Number of the Parallels between the Pole, and the Index, is the Distance sought, in Degrees.

THERE is another Method, invented by *Maurolicus*, which shows the Distance in a pleasant Manner, by drawing a Line in a Circle; from which Method, that of solving it by Calculation proceeds.

ON the Center E (*Fig. 48.*) describe a Circle, BE being one Semidiameter; and let the Arc BA be taken equal to the Difference of Longitude (if it be greater than one hundred and eighty, take it's Complement to three hundred and sixty) and draw AE; then take AF towards B, equal to

the Latitude of the Place A, and from B the Arc BG, equal to the Latitude of B; and let GI, be made perpendicular to BE and FH, from F to AE, draw IH, and on I and H raise perpendiculars IL, equal to IG, and HK equal to HF (the same way if the Latitude be of the same kind, if not then IL is to be drawn on the one Side of IH and HK on the other) then LK will be the Chord of the Distance sought; and with the opening of the Compasses KL, take BX, and you have the Distance in Degrees.

THIS Method is taken from the Solution of spherical Triangles; but the doing of it by drawing Lines doth not give the Distance exact enough; tho' 'tis easy and pleasant; and no other Method by spherical Trigonometry can give it exactly. You have the Complements of the two Latitudes, and the Angle contained, which is the Difference of Longitude, to find the opposite Side, which is the Distance sought; for which there are several Methods, but the most common, and what hath no regard to the variety of Cases here, is this:

1. IF the Latitudes are of one kind, then let it be, As the Square of the Radius is to the Rectangle of the Sines of the Complement of the Latitudes, So is the versed Sine of Difference of Longitudes (if greater than one hundred and eighty, take their Complement to three hundred and sixty) to a certain fourth Number; then take the Difference of the Latitudes, and the Sine of it's Complement; then the fourth Number, found before, compared with this Sine; and if they be equal, then the Distance is ninety Degrees; if less, subtract it, and the Remainder will be the Sine of an Arc, whose Complement is the Distance of the Places; but if greater than the said Sine, subtract the one from the other, and the Remainder will be the Sine of an Arc, which being added to

ninety Degrees, gives the Distance sought in Degrees.

2. IF the Latitudes be of different kinds, then take the Place of one of the Antipodes for the other Place, and find their Distances by the former Method; for the Latitude thereof will be the same, as the other; and there will arise a spherical Triangle, and two Sides given; and the Angle included will be the Complement of the Difference of Longitude to one hundred and eighty Degrees: and having found the Distance between the one Place, and the Antipodes of the other; you have the Distance of the Places themselves for it's Complement of the former to one hundred and eighty, as was said in the preceding Proposition.

IN Places that are nearer the Equator than nineteen Degrees, we may use another easy Method; which tho' not demonstrative, yet will give the Distance pretty nearly. We take the Square of the Difference of Longitude, and the Square of the Difference of Latitude; and their Sum is the Square of the Distance nearly.

OR better thus, which will serve for great Latitudes; find, by the Table before, the Miles in the Parallel of the greatest Latitude; then As the Miles in a Degree on the Equator are to the Miles in a Degree in that Parallel; So is the Difference of Longitude in Miles to a fourth Number; the Square of which added to the Square of the Difference of Latitude in Miles, gives the Square of the Distance.

THE Solution will be the easier if we use the Logarithms, and resolve the oblique Triangle into two right-angled Triangles; for then there will be no need of Multiplication and Division.

PROPOSITION X.

Having the Difference of Longitude of two Places, and the Point on which one lies from the other, to find their Distance.

THIS is no other than having two Sides of a spherical Triangle, and the Angle opposite to one Side, to find the third Side; or having the Complements of two Latitudes, and the Angle of Position, or it's Complement, to one hundred and eighty, to find the third Side.

THE Solution of the Problem by the Globe is thus: Suppose the first Meridian to be the Meridian of the Place, and mark the Latitude for that Place; then elevate the Globe for the Latitude of the other Place, and fix the Quadrant to the Zenith, and turn it 'till it come to the Point given on the Horizon; then turn the Globe 'till the Place whose Latitude was marked come to the Quadrant; then the Arc of the Quadrant between the Zenith and that Point is the Distance sought: at the same time you have the Difference of Longitude on the Equator, or the Arc between the first, and the brass Meridian.

HOW this is to be done by the Planisphere, and by Calculation, with, or without, the Logarithms, I leave to a Master; lest I should say a great deal that would be of little use to many.

PROPOSITION XI.

Having the Longitude of two Places, and the Latitude of one, and the Point in which the other Place lies in from it, to find the Distance.

WE have here again a spherical Triangle whose Sides are the Complements of the two Latitudes,
and

and the Distance of the Places in which we have one Side, the Complement of the Latitude of the one, and two Angles; the one is the Difference of Longitude; and the other the Point made by the Meridian and the Distance, to find the Distance. The Solution by the Globe and the Planisphere is easy, and by Logarithmical Calculation accurate enough; and even by common Calculation: we shall only use the way by the Globe for the Reason before mentioned; though by the Planisphere 'tis easier; but that by the Globe gives the Triangle itself.

SUPPOSE the first Meridian to be that of the place whose Latitude is not given; count the Difference of Longitude on the Equator, and mark the ending with Chalk, and bring it to the Meridian which will be the Meridian of the other place; count on it the given Latitude; and elevate the Pole for that Latitude; the Globe being fixed, bring the Quadrant to the Zenith, and turn it 'till it come to the Point on the Horizon; the Place where the Quadrant cuts the first Meridian will be the one place, and the Arc between the Zenith; and that Point is the Distance sought. And at the same time you will see the Latitude of the other place.

PROPOSITION XII.

Having the Distance of two Places in the same Meridian, and the Points in which a third lies from the other two, to find the Distance of the third from the other two.

WE have here again a spherical Triangle, in which the three Sides are the three Distances of the Places, and one Side is given; the Distance of the two in the same Meridian, and the two

adjacent Angles, and the other two Sides are wanted.

OMITTING the Methods by Calculation, and by the Planisphere (tho' more accurate) we shall give that by the Globe ; which exhibits the thing to the Eye.

TAKE the Distance of the two places in the brass Meridian ; then elevate the Pole for the Latitude of the one, and fix the Quadrant at the Zenith, and bring it to the Point the third place lies in, and draw a Line along it with Chalk ; then fix the Quadrant at the other place brought to the Zenith, and turn it 'till it come to the Point the third place lies in from the second place ; and where it cuts the Arch by the Chalk, you have the third place, whose Distance from the other two is easily measured.





CHAP. XXXIV.

Of the Sensible or Visible Horizon.

THE Sensible Horizon is a Periphery on the Superficies of the Earth, which terminates the Sight all round, or which terminates that Part of the Superficies visible to the Eye, whilst the Spectator turns himself round; or from which Rays can come to the Eye. It's Semidiameter is an Arc of a great Circle on the Earth, between the Foot of the Spectator and the Periphery, which is therefore perpendicular to that Periphery.

PROPOSITION I.

The Extension of the Sensible Horizon is various, according to the Height of the Eye; or as the Semidiameter of the Earth is supposed to be.

Let MPNF (Fig. 49.) be a great Circle on the Earth, T the Center, TP the Semidiameter, PO the Altitude of the Eye, and O the Eye; draw from O the Tangents ON, OM; and let us conceive the Ray NO to be carried round, and to describe a Periphery on the Earth; which will be the Sensible Horizon, whose Semidiameter is PN, PM, for NO, MO, are the last Rays that can come to the Eye from the Earth; which we here suppose perfectly round.

AND 'tis plain if we take a greater or less Altitude PO, then PN will be a greater or lesser

Arc ; and if TP be more or fewer Miles, then PN will be so also.

THESE two seem to be the Causes why the Antients differ so much in their Opinions of the bigness of this Horizon. *Macrobius* makes the Semidiameter of it one hundred and eighty Furlongs, or twenty two Miles and a half ; and *Eratosthenes* three hundred and fifty Furlongs, or forty four Miles ; *Albertus Magnus* a thousand Furlongs, or one hundred and twenty five Miles ; *Proclus* two thousand Furlongs, or two hundred and fifty Miles ; a great many make it five hundred Furlongs, or sixty two Miles and a half : which Diversity proceeds also from the different Lengths of Furlongs, as appears from the following Proposition.

PROPOSITION II.

Having the Height of the Eye above the Ground, and the Semidiameter of the Earth ; to find the Semidiameter of the Sensible Horizon.

Let PO (*Fig. 49.*) be the Man's Stature, O the Eye, TP the Semidiameter, ON the Ray touching the Earth, which terminates that Horizon ; therefore PN is it's Semidiameter, whose Length is wanted : PO being supposed five Foot, is added to the Semidiameter TP , which makes TO 19598300 Feet ; and in the Triangle NTO we have TO and TN , and the Angle TNO ninety Degrees ; the Angle NTO is found thus, As TO is to TN , So is the whole Sine to the Sine of the Angle NOT ; whose Complement is the Angle NTO , or Arc NP , which may be turned to Miles.

COROL.

COROLLARY.

FROM hence we may see, that if TP or PO be taken of different Lengths, there will come out different Degrees in the Arc NP .

PROPOSITION III.

Having the Height of the Eye on a Tower, or Mountain, to find how far the Sight extends on the Sea.

Let PO (Fig. 49.) be the Altitude of the Tower, and work as before; for here the Height of a Man is not considerable.

PROPOSITION IV.

The greatest Length that the Sight extends being given; or the Semidiameter of the Sensible Horizon; to find at what Height the Eye is placed.

OR, which is the same thing, having the greatest Distance that the Top of a Mountain can be seen at, to find the Altitude of the Mountain.

IN the Triangle NTO (Fig. 49.) there is given the Angle at N of ninety Degrees; and the Arc NP , which is the Measure NTO , and the Semidiameter NT , to find TO , from which take TP , and you have PO .

WE may therefore, by supposing a certain Measure of the Semidiameter of the Earth, find, from the Quantity assigned, by different Authors, to the visible Horizon, what Height of the Eye each Author assumed.

PRO-

PROPOSITION V.

Having the Height of the Eye, and the Height of a Ship's Mast, or a Tower, or Mountain, to find their Distance.

Let PO (Fig. 49.) be the Height of the Eye on the Mast of a Ship, or Tower, &c. and FS the Mast of another Ship, then SO will be the first Ray that comes to the Eye from the Top-Mast, the Distance FP is wanted. First from the Triangle NTO ; having NT , and TO , and the Angle TNO , find the Angle NTO , and the Triangle NTS ; having NT , and TS ; and the right Angle TNS ; find the Angle NTS ; thus you have the whole Angle OTS , of which the Arc PF is the Measure.

PROPOSITION VI.

Having the Height of the Eye, and the Distance at which the Ship or Tower is first seen, to find the Altitude of the Tower or Ship.

IN the Triangle NOT , (Fig. 49.) having NT and TO , the Arc NP is found, which being taken from the known Arc PF (the Distance being turned to Minutes of a Degree) leaves the Arc FN , or the Angle NTS . And in the Triangle NTS you have NT , and the Angle N ninety Degrees; you may find the Hypotenuse TS , from which take TF , and you have the Height of the Tower, Ship, &c.

PRO-

PROPOSITION VII.

The Refraction of Light in the Air increases the apparent Semidiameter of the Sensible Horizon.

FOR the Refraction differs in different places, the Air being thicker, the nearer the Earth; and therefore tho' the Ray come from a Point further than N, (*Fig. 49.*) as from F, it cannot come strait to the Eye, yet may be refracted so as to come in the Line NO, which touches the Earth.

IT may not be improper here to observe, that our learned Author is, as it were, the Fountain from whence most of our Geographical Writers have drawn very great Supplies; some have borrowed and acknowledged the Advantages; others have stolen from him, and, in a different Dress and Dialect, have recommended it to the World for their own. It is certain that to borrow from an Author, and to improve upon that Author, is not only justifiable, but has been the chief if not the only means by which the present Age has brought their Acquirements in Philosophy, and Mathematics, to the pitch to which they are now arrived; therefore to do justice to Mr Gordon in his Grammar, and yet to improve Varenus so as to make it the most excellent of it's Kind, the Publisher hath thought proper to add not only some *Theorems* which in themselves are natural and demonstrable Truths, beyond the reach of Contradiction, or even of Dispute; but also some of the most useful of Gordon's *Paradoxes*, with their Solutions, without which the Paradoxes are but of little use except to amuse the Reader, and leave him as much in the Dark as they found him. The *Theorems* follow immediately, and the *Paradoxes* with their Solutions next after them.

G E O.

GEOGRAPHICAL THEOREMS.

Theor. 1. The Latitude of any place is always equal to the Elevation of the Pole in the same place, and *è contra*.

Theor. 2. The Elevation of the Equator in any place is always equal to the Complement of the Latitude in the same Place ; and *vice versâ*.

Theor. 3. Those places lying under the Equinoctial Line have nothing of Latitude, it being there that the Calculation of Latitude begins.

Theor. 4. Those places lying exactly under the the two Poles have the greatest Latitude, it being there that Calculation of Latitude doth end.

Theor. 5. Those places lying exactly under the first Meridian have nothing of Longitude, it being there that the Calculation of Longitude begins.

Theor. 6. Those Places lying immediately adjacent to the western Side of the first Meridian have the greatest Longitude, it being there that the Calculation of Longitude doth end.

Theor. 7. All Places lying upon each Side of the Equator, have the greater or lesser Latitude, according to their Respective distance therefrom.

Theor. 8. All places lying upon either Side of the Equator, and exactly under the same, have the greater or lesser Longitude according to their Respective distance from the first Meridian.

Theor. 9. That particular Place of the Earth lying exactly under the Intersection of the first Meridian and Equinoctial Line, hath neither Longitude nor Latitude.

Theor. 10. No place of the Earth is distant from another above 10800 *Italian* Miles allowing 60 to one Degree in the Equator.

Theor. 11. No place of the Earth is distant from it's proper Antipodes, diametrically taken, above

7200 Italian Miles, still allowing 60 to one Degree in the Equator.

Theor. 12. The sensible Horizon of every place doth as often change as we happen to change the place itself.

Theor. 13. The apparent Semidiameter of the sensible Horizon in most places doth frequently vary, according to the Refraction of the Sun-Beams.

Theor. 14. All Countries upon the face of the whole Earth do equally enjoy the sight of the Sun in Respect of time, and are equally deprived thereof.

Theor. 15. In all places of the Globe of the Earth, save exactly under the Poles, the Days and Nights are of an equal Length, viz. 12 Hours each, when the Sun cometh to the Equinoctial Line.

Theor. 16. In all places between the Equinoctial and the two Poles, the Days and Nights are never equal one to another, save only those two times of the Year when the Sun entereth the Signs of *Aries* and *Libra*.

Theor. 17. The nearer any place is to the Line, the lesser is the difference between the length of the Artificial Days and Nights in the said place: and, on the contrary, the further removed the greater.

Theor. 18. In all places lying under the same Parallel of Latitude, the Days and Nights are of the same Extent, and that at all times of the Year.

Theor. 19. Three or more places being given on the Globe, that lie between the Equator and either of the Poles, and equidistant from one another, the extent of the longest Day in those places doth not encrease proportionably to the distance of the places themselves.

Theor.

Theor. 20. Three or more places being given on the Globe, that lie between the Equator and the Poles, in which the length of the longest Day doth equally increase, the Distance between the Parallel of those places is not equal to one another.

Theor. 21. Three or more places being given on the Globe, whose Distance from the Equator to either Pole exceeds one another in Arithmetical Proportion; the Length of the longest Day in one doth not keep the same Analogy to that in the other, according to the Proportion of their Distance.

Theor. 22. In all places of the *Torrid Zone* the Morning and Evening Twilight is least: in the *Frigid* greatest; and in the temperate 'tis a Medium between the two.

Theor. 23. To all places lying between the Tropics, the Sun is duly vertical twice a Year; to those under the Tropics once; but to them in the Temperate and Frigid never.

Theor. 24. In all places of the two *Frigid Zones*, the Sun appeareth every Year without setting for a certain number of Days, and disappeareth for the same Space of Time. And the nearer unto or the farther from the Pole these places are, the longer or shorter is his continued presence in, or absence from, the same.

Theor. 25. In all places exactly under the Arctic and Antarctic Circles, the Sun at his greatest Declination appeareth every Year, for one Day compleatly without setting, and intirely disappeareth another, but daily riseth and setteth in those Parts at all other Times as elsewhere.

Theor. 26. In all places between the Equator and North Pole, the longest Day and shortest Night is always when the Sun hath the greatest northern

northern Declination, and the shortest Day and longest Night when he hath the greatest Southern.

Theor. 27. In all Places between the Equator and South Pole, the longest Day and the shortest Night is always when the Sun hath the greatest southern Declination; and the shortest Day and longest Night, when the greatest Northern.

Theor. 28. In all places situated under the Equinoctial Line, the Meridian Shadow of a Style perpendicularly erected, doth cast itself towards the North for one half of the Year, and towards the South during the other.

Theor. 29. In all places lying under the Equinoctial Line, there is no Meridian-Shadow on those Days of the Year that the Sun doth enter the Signs of *Aries* and *Libra*.

Theor. 30. The nearer that Places are unto, or the farthest removed from, the Equator, the shorter or longer accordingly is the Meridian-Shadow of a Style perpendicularly erected in such Places.

Theor. 31. The farther that Places are removed from the Equator, yet not surpassing 66 Degrees of Latitude, the greatest is the Sun's Amplitude, or that Arc of the Horizon between the Points of due East and West, and those on which the Sun riseth and setteth on the Days of the Summer and Winter *Solstice*.

Theor. 32. In all places lying under the same Semicircle of the Meridian, the Hours of both Day and Night are always the same in one as in the other.

Theor. 33. In all places both of the North and Southern Hemispheres, that lie under the opposite Parallels of Latitude, the Seasons of the Year are not the same in one, as in the other.

Theor. 34. In all places situated in a parallel Sphere, the Circle of the Sun's Diurnal Motion
runs

runs always parallel, or very near it, to the respective Horizon of such places.

Theor. 35. In all places situated in a right Sphere, the Circle of the Sun's Diurnal Motion is still perpendicular, or very near it, to the respective Horizon of such places.

Theor. 36. In all places situated in an Oblique Sphere, the Circle of the Sun's Diurnal Motion is always oblique unto, or cutteth, the Horizon of such places at unequal Angles.

Theor. 37. If the Difference of Longitude in two Places be exactly 15 Degrees, the People residing in the Eastmost of them, will reckon the time of Day sooner by one Hour, than those in the other. If the Difference be 30 Degrees, then they'll reckon the Hours sooner by two; if 45 Degrees, by three; and if 60, then by four, &c.

Theor. 38. If People residing in two distinct places do differ exactly one Hour in reckoning their Time, it being only Noon to one, when One in the Afternoon to the other, the true Distance between the respective Meridians of those Places is exactly 15 Degrees upon the Equator: If they differ two Hours, the Distance is 30 Degrees; if three, 'tis 45; and if four, 'tis compleatly 60, &c.

Theor. 39. If any Ship set out from any Port, and steering Eastward doth entirely surround the Globe of the Earth, the People of the said Ship in reckoning their time will gain one Day compleatly at their Return, or count one more than those residing at the said Port: If Westward, they'll lose one, or reckon one less.

Theor. 40. If two Ships set out from the same Port at the same time, and both surround the Globe of the Earth, one steering East and the other Westward, they'll differ from one another in reckoning
their

their time two Days compleatly at their Return, even suppose they happen to arrive on the same Day. If they surround the Earth twice, steering as aforesaid, they'll differ four Days; if thrice, then six, &c.

Theor. 41. If several Ships set out from the same Port, either at the same or different time, do all surround the Globe of the Earth, some steering due South, others due North, and arrive again at the same Port, the respective People of those different Ships at their Return will not differ from one another in reckoning their time, nor from those who reside at the said Port.

GEOGRAPHICAL PARADOXES,

With their SOLUTIONS.

Paradox 1. There are two remarkable places on the Globe of the Earth, in which there is only one Day and one Night throughout the whole Year.

Solution. Those two places are mostly all that Space contained within the Polar Circles, as is evident from *Prob.* 15.

Paradox 2. There are also some places on the Globe of the Earth, in which there is only one Day and one Night at a certain time of the Year.

Solution. These two places are the Polar Circles, when the Sun is in the opposite Tropic, as appears from *Prob.* 15 and 16.

Paradox 3. There is a certain place of the Earth, at which if two Men should chance to meet, one would stand upright upon the Soles of the other's Feet, and neither of them should feel the other's Weight, and yet both should retain their natural Posture.

Solution. This place is the Center of the Earth: This Paradox is rendered obscure, by saying a certain place of the Earth, and not in the Earth.

Paradox 4. There is also a certain place of the Earth, where, a Fire being made, neither Flame nor Smoak would ascend, but move circularly about the Fire. Moreover, if in that place one should fix a smooth or plain Table without any Ledges whatsoever, and pour thereon a large Quantity of Water, not one Drop thereof could run over the said Table, but would raise itself up in a large Heap.

Solution. This is likewise the Center of the Earth; but these two last Paradoxes may rather be termed Philosophical than Geographical.

Paradox 5. There is a certain place of the Globe, of a considerable Southern Latitude, that hath both the greatest and least Degree of Longitude.

Solution. Not only a certain place in Southern Latitude, but all places, situated under the first Meridian from Pole to Pole, have the greatest and least Degree of Longitude; because where the utmost Extent of Longitude ends, it's least Denomination begins.

Paradox 6. There are three remarkable places on the Globe, that differ both in Longitude and Latitude, and yet all lie under one and the same Meridian.

Solution. This is to be understood of the Artificial Globe, and the brazen Meridian thereto belonging; then the Difficulty will soon vanish, if we suppose the first place to be situated 10 Degrees of Latitude, and 10 Degrees of Longitude, from any first Meridian, the second place under the North Pole, and the third in 190 Degrees of Longitude under the Tropic of *Cancer*: Then it will appear, that all three places are under the same brazen Meridian of the Artificial Globe, and yet differ both in
Longitude

Longitude and Latitude, for the first place will be in 10 Degrees Longitude and 10 of Latitude; the second in 0 Longitude and 90 Degrees Latitude; the third in 190 Degrees Longitude and $23^{\circ} 30'$ Latitude.

Paradox 7. There are three remarkable places on the Continent of *Europe*, that lie under three different Meridians, and yet all agree in Longitude and Latitude.

Solution. 'Tis supposed that this refers to the Difference among Geographers in fixing their first Meridian. Thus some place it at *Cape de Verd* Islands, and others at *Teneriffe*, one of the *Canary* Islands. Now if you take three places in *Europe* to make it correspond with the Paradox, in the same Latitude, at 10 Degrees distant from one another, and supposing each place to be the first Meridian, they all agree in Latitude, and also in Longitude, and yet lie under three different Meridians in respect of the Globe.

Paradox 8. There is a certain Island in the *Ægean* Sea, upon which if two Children were brought forth at the same instant of Time, and living together for several Years, should both expire on the same Day and Hour, yet the Life of the one should surpass the Life of the other by divers Months.

Solution. This Paradox may be solved two ways:

1. If one of the Children sail directly East, and the other directly West, when they encompass the Globe, which may be done in a Year, there will be two Days difference in their Ages; and in 40 Years thus sailing, the one will be 80 Days older than the other.

2. Otherwise, if we suppose the one to live within the Artic Circle, where no Day exceeds 24 Hours; and the other lives within either of

the Polar Circles, as under $73^{\circ} 20'$, where the Day is three Months long, and then returns, and both die, the one will be three Months older than the other.

Paradox 9. There are two observable places belonging to *Asia*, that lie under the same Meridian, and of a small Distance from one another, and yet the respective Inhabitants, in reckoning their Time, do differ an entire natural Day every Week.

Solution. Not only in *Asia*, but every where else, where *Christians* and *Jews* inhabit together, the latter reckon their Sabbath one Day every Week sooner than the former.

Paradox 10. There is a particular place of the Earth, where the Winds, tho' frequently veering round the Compass, do always blow from the North.

Solution. At the South Pole.

Paradox 11. There is a certain Hill in the South of *Bohemia*, on whose Top, if an equinoctial Sun-Dial be duly erected, a Man that is Stone-blind may know the Hour of the Day by the same.

Solution. If a Burning-Glass be the *Nodus* of a Dial, and so contrived, that the *Focus* may fall on an iron or brass Plate or Ring, on which the Figures are deeply cut, a blind Man may feel where the Plate or Ring is heated by the Sun, and which Figure it is upon, or nearest to.

Paradox 12. There are a considerable number of Places lying within the *Torrid Zone*; in any of which, if a certain Sun-Dial be duly erected, the Shadow will go back several Degrees upon the same at a certain time of the Year, and that twice every Day for the Space of divers Weeks, yet no ways derogating from that miraculous returning of the Shadow upon the Dial of *Abaz* in the Days of King *Hezekiah*.

Solution.

Solution. This Paradox may be solved by explaining the nature of concave, convex, and reflecting Dials ; but as one certain kind of Dial is mentioned, we may suppose a plain equinoctial Dial described on both Sides of an horizontal Plane with two Gnomons, and near the Tropic, when the Latitude and Declination are equal ; before the Sun comes to the mathematical Horizon in the Morning, he will shine on the lower Side of the Plane, and the Shadow of the Gnomon will run Westward ; and presently after six o'Clock, as he shines on the upper Plane, the Shadow will run Eastward 'till Noon, and thence to six in the Evening, at which time the Shadow on the lower Plane will begin and run Eastward 'till Sun-set.

Likewise it may be considered, that any where in the *Torrid Zone*, where the Latitude is less than the Sun's Declination, and both towards the same Pole, the Sun comes twice to the same Point of the Compass both Forenoon and Afternoon ; and an equinoctial Dial placed horizontally, the Shadow of the Gnomon shall go back twice every Day.

Paradox 13. There are divers places on the Continent of *Africa* and the Islands of *Sumatra*, where a certain kind of Sun-Dial being duly fixed, the Gnomon thereof will cast no Shadow at all during several Seasons of the Year, and yet the exact time of the Day may be known thereby.

Solution. Horizontal Dials within the Tropics cast no Shadows at 12 o'Clock twice every Year ; nor will any universal Ring-Dial shew the Hour in any Latitude, when the Sun is in either Equinox.

Paradox 14. There is a certain Island in the vast *Atlantic Ocean*, which being described by a Ship at Sea, and bearing due East of the said Ship, at 12 Leagues distant by Estimation, the truest

Course for hitting the said Island is to sail six Leagues due East, and just as many due West.

Solution. If it be supposed, that the first Meridian from whence Longitude is reckoned both ways, passes in the Middle between the Ship and Island; then Regard is had to the East and West Longitude and not to the Points of the Compass.

Paradox. 15. There is a remarkable Place on the Globe of the Earth of a very pure and wholsom Air to breath in, yet of such a strange and detestable Quality, that 'tis absolutely impossible for two of the entirest Friends that ever breathed to continue in the same, in mutual Love and Friendship for the Space of two Minutes of Time.

Solution. 'Tis certainly impossible for two Bodies of any kind to be in one and the same Place at the same Time.

Paradox 16. There is a certain noted Place in the vast *Atlantic* Ocean, where a brisk *Levant* is absolutely the best Wind for a Ship that is to shape a due East Course, and yet she shall still go before it.

Solution. This Paradox may be solved several ways :

1. If the Place be Eastward of the *Levant*, a Ship may be carried by an East Wind round the Globe to it, provided some East Point be fixed.

2. 'Tis the Case in the Gulph of *Florida*, where there's a violent Current, as is well known to most Seamen that have been in the *West-Indies*.

Lastly, An East Wind may be best to carry a Ship out of an Harbour, that is to sail or make an Eastern Voyage, as in the Port of *London*, a Western Wind is best to bring such Ships out of the *Thames*, tho' bound to the *West-Indies*.

Paradox 17. There are divers remarkable Places upon the Terraqueous Globe, whose sensible Horizon

zon is commonly fair and serene, and yet 'tis impossible to distinguish properly in it any one of the intermediate Points of the Compass, nay, not so much as the two of the four Cardinal Points.

Solution. This must be meant under either of the Poles.

Paradox 18. There is a certain Island in the *Baltic* Sea, to whose Inhabitants the Body of the Sun is clearly visible in the Morning before he riseth, and likewise in the Evening after he is set.

Solution. There is no Difficulty in this Paradox to any one who is acquainted with the Nature of Refraction; but to such who are not, if they please to put a Sixpence into a Vessel of Water, and stand at such a Distance that they can just see the Sixpence, or any other piece of bright Metal; and when the Vessel is empty they cannot see the Metal at the same Distance: So the watry Vapours, near the Horizon, causes the Sun to appear to be higher than he really is.

Paradox 19. There is a certain Village in the Kingdom of *Naples* situated in a very low Valley, and yet the Sun is nearer to the Inhabitants thereof every Noon by 3000 Miles and upwards, than when he either riseth or setteth to those of the said Village.

Solution. When the Sun riseth in the Horizon of any Place, be it *Naples* or any where else, he is the Space of the Earth's Semidiameter more distant from that Place than in his Meridian at Noon. Now there being but an inconsiderable Proportion between the Depth of the lowest Valley in the World and the Semidiameter of the Earth, which is near 4000 Miles, it follows, that the Sun must be 3000 Miles and upwards nearer at Noon than at his rising, there being no Valley the tenth part of 1000 Miles deep.

Paradox 20. There is a certain Village in the South of *Great Britain*, to whose Inhabitants the Body of the Sun is less visible about the Winter Solstice than to those who reside on the Islands of *Iceland*.

Solution. 'Tis very possible that there may be one or more Villages, not only in the South of *England*, and particularly in *Suffex*, but in a more Southern Latitude, so situated on the North-side of a Hill whose Height may intercept the Sun several Days before and after the Winter Solstice from the Inhabitants of that Village.

Paradox 21. There is a vast Country in *Ethiopia Superior*, to whose Inhabitants the Body of the Moon doth always appear to be most enlightened when she is least enlightened, and to be the least when most.

Solution. The Light that falls upon any Body being always in a reciprocal duplicate Ratio of the Distance from the luminous Body, it follows, that not only in *Ethiopia*, but in all Parts of the World, the Moon doth always appear to be most enlightened at the Full Moon when she is least enlightened, because she is then removed from the Sun farther than at New Moon, by the Diameter of the Moon's Orbit.

Paradox 22. There is a certain Island, whereof mention is made by several of our latest Geographers, whose Inhabitants cannot properly be reckoned either Male or Female, nor altogether Hermaphrodites; yet such is their peculiar Quality, that they are seldom liable either to Hunger or Thirst, Cold or Heat, Joy or Sorrow, Hopes or Fears, or any such of the common Attendants of human Life.

Solution. Trees or Shrubs growing on an Island not inhabited by Animals or Puppets, may be called Inhabitants, either will answer this Paradox.

Paradox 23. There is a remarkable Place of the Earth, of a considerable Southern Latitude, from whose Meridian the Sun removeth not for several Days at a certain time of the Year.

Solution. Under the South Pole, or within the Artic Circle, the Sun enlightens the Meridian by shining constantly upon it for 30 Days together.

Paradox 24. There is a certain Place of the Earth, of a considerable Northern Latitude, where tho' the Days and Nights, even when shortest, do consist of several Hours, yet in that Place 'tis Mid-Day or Noon every Quarter of an Hour.

Solution. Under the North Pole.

Paradox 25. There are divers Places on the Globe of the Earth, where the Sun and Moon and all the Planets do actually rise and set according to their various Motions, but never any of the fixed Stars.

Solution. Under the Poles the Planets, by their Motions, get North or South Declination, consequently rise and set with relation to those two Places: but the fixed Stars keeping an exact Distance from the Pole may be said never to rise or set.

Paradox 26. There is a remarkable Place on the Terraqueous Globe, where all the Planets, notwithstanding their different Motions and various Aspects, do always bear on one and the same Point of the Compass.

Solution. Under either of the Poles of the World.

Paradox 27. There is a certain noted Part of the Earth, where the Sun and Moon, tho' it be the very instant of Time the Moon is at full, yet they may both happen to rise at the same instant of Time and upon the same Point of the Compass.

Solution. Under the North Pole, the Sun and Full Moon, both decreasing in South Declination and Latitude, will rise in the equinoctial Points at
the

the same Moment, and under the North Pole there is no other Point of the Compass but South.

Paradox 28. There is a certain Place on the Continent of *Europe*, where if several of the ablest Astronomers the World now affords should nicely observe the Celestial Bodies, and that at the same instant of Time, yet the Planetary Phases, and their various Aspects, would be really different to each of them.

Solution. Neither at the Center, or any part of the Earth, no one can observe all the Celestial Bodies at one and the same instant of Time, and consequently will appear different, because they are constantly in Motion.

Paradox 29. There is a large and famous City on the Continent of *Africa*, many of whose Inhabitants are born perfectly deaf, and others stone-blind, and continue so during their whole Lives; and such is the amazing Faculty of those Persons, that the Deaf are as capable to judge of Sounds as those that hear, and the Blind of Colours as they who see.

Solution. The Blind and Deaf have Capacity to judge of Colours as they who see and hear, though they want the Senses of seeing and hearing.

Paradox 30. There is a certain People in South *America* who are properly furnished with only one of the five Senses, viz. that of Touching, and yet they can both hear and see, taste and smell, and that as nicely as we *Europeans* who have all Five.

Solution. All the Senses are properly by the Touch; in seeing, the Object touches the Retina; hearing, the Sound touches the Drum of the Ear; smelling, the Effluvia touch the Sensorium; tasting, the Palate, &c.

Paradox 31. There is a certain Country in South *America*, many of whose savage Inhabitants are such unheard of Cannibals, that they not only feed upon

upon human Flesh, but some of them do actually eat themselves, and yet they commonly survive that strange Repast.

Solution. The mystery of this Paradox depends only on the Word themselves; for if they don't eat their Meat themselves no Body can eat for them so as to sustain their Life.

Paradox 32. There is a remarkable River on the Continent of *Europe*, over which there is a Bridge of such a Breadth that above 3000 Men may pass a long upon the same a-breast; and that without crowding one another in the least.

Solution. There are several places in *England*, and other parts, where Rivers run a considerable Way under Ground; as the *Guadiana* in *Spain*, and the Mole in *Surrey*; the latter runs from *Darking* to *Leatherhead* under Ground, being upwards of four measured Miles, are more than 7000 Yards which will allow near seven feet to each Man, in Breadth, to walk if there were 3000 Men to march a-breast.

Paradox 33. There is a large and spacious Plain in a certain Country of *Asia*, able to contain 6000 Men drawn up in Battle Array, which number of Men being actually brought thither and there drawn up, it were absolutely impossible for any more than any one single Person to stand upright upon the said Plain.

Solution. By the 13 E. 3 of Euclid, a Plain can touch a Sphere only in one Point called the Contact, and that Person only who stands on that Point with respect to the Center of the Sphere, can stand upright.

Paradox 34. There is a certain *European* City whose Buildings being generally of firm Stone, are for the most Part of a prodigious Height, and exceeding strong, and yet it is most certain, that the Walls of those Buildings are not parallel
to

to one another, nor perpendicular to the Plain on which they are built.

Solution. All Walls are endeavoured to be built perpendicular to the Tangent, and point to the Centre of the Earth, where they, if continued, would meet in a Point, and consequently are not Parallels, and but in one Point only can a Perpendicular be raised on an horizontal Plain, as is evident from the Proposition in the preceding Paradox.

Paradox 35. There is a certain City in the Southern part of *China*, whose Inhabitants both Male and Female do observe almost the same Posture, and Gait in walking, as we *Europeans*, and yet they frequently appear to Strangers as if they walked on their Heads.

Solution. In *China* and all other places where the Inhabitants stand near the Sea, or any standing Water that is clear, Strangers or others standing by them and looking on it, must see them as tho' their Heads were downward by the refracted Vision.

Paradox 36. There are ten places of the Earth distant from one another 300 Miles and upwards, and yet none of them have either Longitude or Latitude.

Solution. These ten places must be supposed to be in the Earth, and not upon it; for Longitude and Latitude are reckoned on the Surface of the Globe only; so the Axis of the Earth, or any other imaginary Line through it, being about 7200 Miles, will not only answer the Paradox, but if it had been said twenty four Places, it would have kept within the Possibility of the demand.

Paradox 37. There are two distinct places of the Earth, lying under the same Meridian, whose Difference of Latitude is sixty Degrees compleatly, and yet the true Distance between those two places doth not really surpass sixty *Italian Miles*.

Solution.

Solution. The two places are not meant on the Superficies of the Earth, as you may perceive by the Word of, and not upon; then the places will be so near the Center of the Earth, as two Lines supposed to come one from 0 Latitude, the other from 60° Latitude, and to meet in the Centre, may approach within the Distance of 60 *Italian Miles*.

Paradox 38. There are also two distinct places of the Earth lying under the Equinoctial Line, whose Difference of Longitude is compleatly eighty six Degrees and a half; and yet the true Distance between those two places is not full eighty six *Italian Miles*.

Solution. The two Places, as in the foregoing Paradoxes, must be supposed to be within the Earth; and even at forty Miles Distance from it's Center, will sufficiently answer the Paradox.

Paradox 39. There are three distinct Places of the Earth, all differing both in Longitude and Latitude, and distant from one another 2000 Miles compleatly, and yet they all bear upon one, and the same Point of the Compass.

Solution. All places differing both in Longitude and Latitude, at what Distance soever with Respect to the Poles, bear upon the same Point of the Compass, or they may be in the same spiral Rhomb.

Paradox 40. There are three distinct places on the Continent of *Europe*, equidistant one from the other, they making a true equilateral Triangle, each of whose sides doth consist of a thousand Miles; and yet there is a fourth place so situated in respect of the other three, that a Man may travel on foot from it to any of the other three in the Space of one artificial Day, at a certain Time of the Year, and that without the least Hurry or Fatigue whatsoever.

Solution.

Solution. By an artificial Day is here meant from Sun rising to Sun setting, and beyond the Tropics and nearer the Poles the Days are encreased when the Sun comes on that side the Equator, from twenty four Hours to about a hundred Days long; so that there would not be a necessity of travelling above four Miles every twelve Hours; to compleat the Terms of the Paradox.

Paradox 41. There are three distinct places on the Continent of *Europe*, lying under the same Meridian, and at such a Distance that the Latitude of the third, surpasseth that of the second, so many Degrees and Minutes exactly, as the second surpasseth the first, and yet the true Distance of the first and third from the second, or intermediate place, is not the same by a great many Miles.

Solution. The Figure of the Earth being not exactly round, as is generally conceived, but what it termed by Geometricians an oblate Spheroid, which is the Shape of a Bowl, so that the Axis is shorter than the Diameter, consequently will cause such a Difference as expressed in the Paradox.

Paradox 42. There are two distinct places on the Continent of *Europe*, so situated in respect of one another, that tho' the first doth lie East from the second, yet the second is not West from the first.

Solution. If the artificial Globe is placed in an oblique Position, then it will appear, tho' two places bear due East and West from one another, yet measured by the Quadrant of Altitude, they will not answer to the true bearing as they are on the natural Globe.

Paradox 43. There is a certain *European* Island, the Northermost Part whereof doth frequently alter both it's Longitude and Latitude.

Solution. There are floating Islands in several Parts of the World, and whenever they are moved
from

from one Place to another, not only the northern, but every Part alters in Longitude and Latitude.

Paradox 44. There is a certain place in the Island of *Great Britain*, where the Stars are always visible at any time of the Day if the Horizon be not overcast.

Solution. In a deep Well or Coal-pit the surrounding Light which the Atmosphere spreads in the open Air, does not press on the Sight; so that if the Shaft of the Well or Pit be strait, and there be Stars in or near the Zenith after stedfastly looking up a Minute or two, you'll discover them; hence several Astronomers have had Wells for that purpose.

Paradox 45. It may be clearly demonstrated by the Terrestrial Globe that it is not above twenty four Hours sailing from the River of *Thames* in *England*, to the City of *Messina* in *Sicily*, at a certain time of the Year, provided there be a brisk North Wind, a light Frigate, and an Azimuth Compass.

Solution. This is meant of the Artificial Globe, and Hour-Index.





C H A P. XXXV.

*Of the three Parts of the Art of Navigation;
and first of the Structure of a Ship.*

P R O P O S I T I O N I.

*The Art of Navigation teaches how a Ship may be
commodiously and safely brought from one Place to
another, thro' the Sea, by the Help of the Wind.*

AND because the Situation of one Place with another is considered in this Part; this Doctrine is justly brought in here in the Comparative, or Relative, Part of Geography.

AND I think in this Art (that is so noble and useful to human Society) there are properly three Parts; 1. Of the Structure of a Ship; to which may be referred the Ship's Motion in the Water. 2. Of the Burden to be carried in the Ship. 3. The governing of the Ship, which is called, in general, the Art of Navigation, by way of Excellency; and is the chief Part thereof; the other two belonging principally to Mechanics and Statics; whereas the directing of the Ship depends wholly upon Geography.

P R O-

PROPOSITION II.

In building a Ship these things are to be considered.

1. THE Choice of the Wood or Matter that will last longest in the Sea ; for which see *Vitruvius*, and other Authors : and here also is to be considered how the Wood is to be prepared, it's Density increased, and the useless Moisture taken away by Fire ; and also defended from Corruption by covering with Pitch, &c. which natural Philosophy teaches.

2. THAT such a Figure be given to the Ship which is fittest for Motion in the Sea, and requires the least Force to move it. To this belongs the different Shapes of the antient and modern Ships, wherein several things worthy to be known may be produced from Antiquity and modern Inventions ; and several things proposed from Statics and Phoronomics, concerning the Motion of Bodies of different Figures ; especially what the divine *Archimedes* hath left us of the Motion of Bodies in Water : but seeing few delight in such things, and our Design is only to give a Compendium of general Geography, I thought fit to omit the Explication of these things, and to enumerate only the Heads and Parts of that Doctrine : which I shall also do in what follows. And if we shall understand that these things are acceptable to Youth, we shall add them in another Edition, fully explained ; and other things likewise, to the preceding Chapters.

BUT to return ; a good Shape is a great Matter for moving easily and swiftly in the Water ; and for this chiefly are Ships commended, especially in Sea-Fights : and there is a great Difference found among Ships in this particular

but this depends on Statics, and the Laws of Motion.

3. IN the Structure of a Ship, it's Figure is to be such as that it may be easily defended against Storms and Waves, that it may not be overfet; but of this more in the second Part, of the Ship's Burden. This also belongs to Statics, and the Motion of Fluids, as Air or Water.

4. THE bigness of a Ship is to be considered; where several things may be advanced by comparing Antiquity with the present Time. The Ship *Alexandrina*, made by the Command of *Hiero*, King of *Sicily*, and sent as a Present to *Ptolemy*, King of *Egypt*, *Archimedes* being the Builder, was thought to be twelve thousand Tun; and *Callixenus* writes, that *Philopator's* Ship was two hundred eighty Cubits long, thirty eight broad, and forty eight high. The biggest ships at present are those of the *Spaniards* and *Portuguese*, which they call *Caracs*, which carry One thousand and more *Vebes* or Lafts, as the *Germans* call them; each being twelve Tun. The *Dutch* Ships do not carry above seven hundred Lafts (*f*).

5. THERE belongs chiefly to the Structure of a Ship, the Knowledge of the building of the Keel, the Rudder, the Ribs, the Stern, and Fore-part, the Masts, the Sails, the Cables, the Anchors; of which not only the Matter, Figure, and Consistency, but also their Bulk and Weight is to be considered.

(*f*) Here seems to be some considerable Mistake about the Burden of Ships; for by *Dolia*, or Tuns, the Author expressly declares, that the means twenty hundred Weight. See

Chap. xxxiv. Prop. 1. But the largest Ships of Burden in *England* and *Holland* seldom exceed six or seven hundred Tun. See also *Prop. 8.* of the next Chapter.

6. TO this also belongs the Knowledge of helping the Fractures, or other Faults of a Ship, by which too much Water is let in.

FOR which purpose 'tis usual in failing, to take a Ship-Carpenter along with them.

AND so much for the first Part of Navigation ; viz. the Art of Ship-building ; which we have but briefly touched upon.





C H A P. XXXVI.

*Of a Ship's Burden; which is the second Part
in Navigation.*

P R O P O S I T I O N I.

The Burden of a Ship is expressed by Lasts or Tuns.

A Ship's Tun is two thousand Pound Weight,
and a Last twelve Tun, or twenty four
thousand Pound Weight.

P R O P O S I T I O N II.

*All Bodies, that are lighter than Water, appear in
some Measure above the Water, floating on it; but
if heavier, they sink; and if of equal Weight, they
keep any Place that is given in it.*

TO this belongs the Knowledge of the different Weights of different Bodies, as Lead, Gold, Iron, Wheat, Sand, Oil, Wine, whose Weights may be compared with that of Water.

C O R O L L A R Y

FROM this it appears, that the Weight of the Ship, and it's Burden must be less than the Weight of as much Water, as is equal to the Solidity

lidity or Capacity of the whole Ship. See Prop. vi. following.

PROPOSITION III.

The nearer a Ship comes to a cubic Figure, that is of equal Length, Breadth, and Thickness, it will bear the greater Weight.

THE Demonstration of this is derived from the Doctrine of Statics.

PROPOSITION IV.

Two things are to be regarded in loading of a Ship ;

- 1. Not to load her so far as that the Burden, with the Ship's Weight, be equal to, or greater than, a Bulk of Water, equal to the Capacity of the Ship, or it's Solidity, tho' it must not be much less, or else there must be Ballast added.*
- 2. The Depth of the Waters thro' which the Ship is to sail must be considered.*

FOR tho' the Weight of the Water will admit the Weight of a Ship, and it's Burden when it's Weight is less than the Water of an equal Bulk with the Ship ; yet if the Water have a less Depth than the Quantity of the Ship, under the Superficies of the Water, the Ship will touch the Ground, and stop there. And therefore the Spaniards put a greater Burden on their Ships than the Dutch, because their Points and Shores are deeper ; and so bigger Ships can go to Zeeland than to Holland.

PROPOSITION V.

If a Ship be so loaded that it's Weight be nearly equal to the Weight of the Sea Water, of an equal Bulk with the Ship, it will not sink; but when it comes to a River it will.

THE Cause is, that River Water is lighter than Sea Water; if therefore the Weight of a loaded Ship be nearly equal to the same Bulk of Sea Water, it will be greater than the same Quantity of River Water; and therefore the Ship sinks. And thus have many Ships been sunk, thro' the unskilfulness of those that loaded them; and by not being unloaded before they come to the River. What the Burden should be, may be known from the Proportion of the Sea Water to River Water, as in *Prop. 8.*

PROPOSITION VI.

Any Body swimming in Water hath the same Weight as Water of an equal Bulk with the Part under Water.

COROLLARY.

HAVING the Quantity of the Ship under Water, you may find the Weight of the Ship, and it's Burden; for the Weight of the Water is, or may easily be known. For example; Suppose a cubical Foot of Water to be seventy Pounds, and if the Part of the Ship under Water be two thousand cubical Feet, then the Water equal to the Part of the Ship under Water will be one hundred and forty thousand Pound; and so much should the Weight of the Ship and Cargo be.

PRO-

PROPOSITION VII.

If a Body be placed in Waters of different Weights, the Part immersed in the lighter Water, hath that proportion to the Part immersed in the heavier, that the Weight of the heavier Water hath to that of the lighter.

PROPOSITION VIII.

A Ship is generally allowed to bear such a Burden as is equal to the Weight of one half of the Bulk of Water, that the Ship can contain.

SUPPOSE a Ship contain 500.000 Tun, each being 2000 Pound; that is, if it contain 1000.000.000 Pound, it will bear 250.000 Tun, or 500.000.000 Pound. And thus we are to understand them, when they say, a Ship is of such a Burden.

THE *Spanish* Caracs carry twelve hundred Lafts; but the largest *Dutch East-India* Ships not above eight hundred.

PROPOSITION IX.

The greater the Ship's Burden is, the less the Ship is tossed by Storms: a Ship of two thousand Tun can bear a Storm that will damage a Ship of three hundred, or seven hundred Tun.

MORE might be added here of lessening a Ship's Burden, and of the different Weight in the Stern, Fore-part, or Middle; and of raising a Ship that is sunk, &c. but being upon this Subject it may not be amiss to subjoin the following Directions, how, by having the Dimensions of a Ship given,

given, to find her Tunnage or Burthen, and the general Rule amongst the Ship-Wrights about *London*, is to multiply the Length by the Keel by the Breadth at the Mid-Ship's Beam, and that product by half the Breadth at the Beam, the last product, divided by 94, will give, in the Quotient, the Burthen of the Ship,

Example.

SUPPOSE a Ship 72 Foot by the Keel, and 24 Foot by the Beam; what is the Tunnage or Burthen of the Ship.

$$\begin{array}{r}
 \text{Keel} \text{ --- } 72 \\
 \text{Beam} \text{ --- } 24 \\
 \hline
 288 \\
 144 \\
 \hline
 1728 \\
 \text{Half the Breadth} \text{ --- } 12 \\
 \text{Divided by} \text{ --- } 94 \overline{)20736} \left(220 \frac{56}{94} \right. \\
 \underline{193} \\
 56
 \end{array}$$

THE Ship's Burthen is 220 Tuns and more than one half.

THERE is another Method of finding the Tunnage, by having the Length by the Keel, the Breadth by the Beam, and the Depth in the Hold, given to find the Burthen; but as the Breadth at the Beam in Ships of Burthen is nearly proportionable to the Depth in the Hold, we shall at present content our selves with the Method above, as being the most expeditious and true, as well as the most commonly used.



CHAP. XXXVII.

Of the third and chief Part of the Art of Navigation, which consists in directing and governing a Ship; and the Sub-division of it into four Parts.

PROPOSITION I.

This Art consists in governing and directing a Ship to such a Point (in whatever Part of the Sea it is) as will bring it to the designed Port without Danger.

THERE are four Parts therein; 1. Special Geography, or the Knowledge of the Space between the two Places, and of it's Properties. 2. The Knowledge of the Points they lie in from one another, at any time. 3. The Knowledge of the Way thro' which the Ship is to be brought to the Place designed; for there are between every two Places an infinite Number of Lines. 4. The Knowledge of the Situation of each Place come to; and how it lies from the Place designed.

THIS is the chief Art of guiding a Ship.

PROPO.

PROPOSITION II.

The Knowledge of the intermediate Space comprehends the following Particulars.

1. A Knowledge of the Situation of Lands, and their running out into the Sea ; the winding of Shores, of Promontories, Mountains, Bays, and Sand-Banks ; the depth of the Water of Streights, Islands, and the certain Marks of each Shore, or part of the Sea ; and the Aspect that Lands on the Shores have at such and such Places ; and the depressing or rising of the Shore : which are found from special Geography, and Sea-Charts ; but most easily by Practice in sailing oft to such Places ; for which reason some are fitter to guide a Ship to one Place than another.

2. THE Knowledge of the general and special Winds, and the proper and stated Winds in a Place, which is chiefly necessary in sailing in the *Torrid Zone*, and Places near it ; for here the general Winds, and in many Places the anniversary Winds, called *Monsoons*, prevail ; and either hinder or forward the Voyage ; for the *Indian Sea* is sailed with such Winds. We spoke largely hereof in *Chap. 20.* and of the stated Storms and Signs thereof : all which the Master of the Ship should know ; and we gave an Example of the Loss sustained for want of Knowledge therein, in the same Chapter.

3. THE Knowledge of the Points that the Sea and Waves are carried to, and carry the Ship with them, which differ in many Places, as in *Chap. xvii*, especially the Knowledge of the Flowing and Ebbing of the Sea, is requisite, and the time when
it

it begins to rise and fall every Day; for without this a Ship is in great danger near the Shores and Sand-Banks, most of which hinder a Ship's Course at low Water, which they do not at high Water: and sailing is also easier towards Land, at the Flowing, and more difficult at Ebbing. We touched upon the Ebbing and Flowing of the Sea in a *Prop.* of *Chap.* xiv. but in some Cases a more accurate Knowledge is requisite as to the true cause of the ebbing and flowing of the Sea; and the Knowledge of this being of such great use towards the forming a just Idea of the General Theory of the Tides, as to it's various Motions, and other Accidents and Circumstances that attend it: I shall here subjoin

Of the General Motion of the Tides, and the true Cause of the Flowing and Ebbing of the Sea.

VARIOUS have been the Conjectures of different Authors, with respect to the Tides, some of which are liable to Contradiction from the very first Principles of Astronomy as hinted in the Note (g), *Prop.* xii. *Chap.* xiv; nor can we in reason allow the Opinion that *Des Cartes* advances in *Prop.* xi, of the same Chapter; where he assigns the pressure of the Moon's Orb upon the Water, or fluid part of this Terraqueous Globe, to be the Cause of the different Height of the Water, or as we call it high and low Water; for if we suppose this, these two absurdities would follow; First, If the Tide was governed by that principle of the Pressure of the Moon's Orb, it would naturally incline to be low Water where the Moon is vertical, or indeed in any part of the Meridian, and high Water when the Moon is in the Horizon, or furthest distant from the Meridian, but the contrary is evident, and it would naturally be high Water when the
Moon

Moon is vertical ; or any where in the Meridian and low Water, when horizontal, &c. except (as it commonly happens near the Coast) that the interjacent Land obstruct or divert the natural Course of the Tide, and not only cause the high Water to happen at a time far different from that of the Moon's southing, but cause the Flood to set upon a different Point than to the westward ; though if the Tide did not meet with those Impediments, and other Accidents, it would not be liable to those Mutations, or Alterations, either in point of Time or Motion. See *Chap. xiv. Prop. vii. and Prop. xviii.* Secondly, If the Fluctuation of the Tides be occasioned by the Pressure of the Moon's Orb ; or, in other words, if her centrifugal Force, if it may be so called, be such, that the Extremity of her Orb be able to depress the Water, or fluid part of this terraqueous Globe, at so great a distance as the Earth is from the Moon ; and if we allow that undeniable Maxim in Philosophy, that *the nearer the Cause the stronger the Effect* ; it would follow, that That Principle that could repel or depress the Waters at the distance of this Earth, would separate the Moon into an infinite number of Atoms ; and the particles of Matter of which she consists, would be diffused and dis-united by that very principle, the contrary of which (*viz.* centripetal Force or a natural Tendency to her Center) keeps her together ; but if we allow the Moon to act upon all Fluids that are within the Orb of her Attraction, or, which is the same, her Gravitation towards her Center, and that this Influence extends to the Earth, so far as to act visibly upon the fluid part of the Water, which common Experience proves, it will necessarily follow, that the Sea will have a natural, tho' weak tendency towards the Moon, and that, as above asserted, it would be high Water where the Moon is vertical, or some where in
the

the Meridian if no Obstructions or Accidents interposed,

AND for a further experimental Proof of this, let us a little trace the observed Motion of the Tides, and we shall find room enough to conjecture, or rather be able to prove, that the true and natural Motion of the Tide is from East to West; and that it would always be high Water when the Moon is upon the Meridian; if the Earth was all over covered with Water equally as deep as the Sea is in the deep parts of it; and that the Irregularity of the Tide is generally occasioned by those parts of the Earth that appear above the Surface of the Water, and intercept it's western Motion; as for Instance,

AS the Sea has no visible Passage between *Europe* and *Africa*, let us suppose them both to be one main Continent extending from 72 North to 34 South, the middle between these two would be in Latitude 19 Degrees North, near *Cape Blanco* upon the West Coast of *Africa*; but it is impossible that the flood Tide should set to the westward upon the West Coast of *Africa*, because the main Continent for above fifty Degrees North, and as much South, bounds that Sea on the East, and therefore if any regular Tide, as proceeding from the Motion of the Sea, from East to West, should reach this place, it must either come from the North Cape Southward, or from the *Cape of Good Hope*, or the South Cape of *Africa*, to the Northward, to the assigned Latitude upon the West Coast of *Africa*.

THIS Opinion is further corroborated, or rather fully confirmed, by common Experience, that the flood Tide sets to the Southward along the West Coast of *Norway*, from the North Cape to the *Naze*, or Entrance of the *Baltic* Sea, and so proceeds to the Southward along the East Coast
of

of *Great Britain*, and in it's passage supplies all those Ports with the Tide one after another, the Coast of *Scotland* having the Tide first, because it proceeds from the Northward to the Southward; and thus on the Days of the full or change, it is high Water at three Quarters past 12, but at *Tinmouth-Bar*, the same Day not till 3. From thence rolling to the Southward it makes high Water at the *Spurn* a little after 5, (but not till 6 at *Hull*, by reason of the time required for it's passage up the River) from thence passing over the Well into *Yarmouth Road*, it makes high Water in *Yarmouth Road* a little after 8, but in the *Pier*, not till 9, and it requires near an Hour more to make high Water at *Yarmouth Town*; in the mean time setting away to the Southward, it makes high Water at *Harwich* at half an Hour after 10, at the *Nore* at 12; at *Gravesend* half an Hour past 1, and at *London* at 3, all in the same Day; and although this would seem to contradict that Hypothesis, of the natural Motion of the Tide being from East to West, yet as no Tide can flow West from the main Continent of *Norway*, or *Holland*, or out of the *Baltic*, which is surrounded by the main Continent, except at it's Entrance, it is evident, that the Tide we have now been tracing by it's several Stages from *Scotland* to *London*, is supplied by the Tide whose original Motion is from East to West; yet as Water always inclines to the level, it will in it's passage fall towards any other Point of the Compass, to fill up vacancies where it finds them, and yet not thereby contradict but rather confirm the first Hypothesis.

WHILE the Tide or high Water is thus gliding to the Southward along the East Coast of *England*, it also sets to the Southward along the West Coast of *Scotland* and *Ireland*; and coming about to the South part of *Ireland*, a Branch
of

of it falls into *St George's Channel*, the Flood running up North-East, as may be naturally inferred from it's being high Water at *Waterford*, above three Hours before it is high Water at *Dublin* or thereabout on that Coast, and it is three quarters of an hour Ebb at *Dublin* before it is high Water at *Isle of Man*, &c.

BUT not to proceed further in particulars than our own, or the *British Channel*, we find the Tide sets to the Southward from the Coast of *Ireland*, and in it's passage a Branch of it falls into the *British Channel* between the *Lizard* and *Ushant*; it's progress to the Southward may be easily proved, by it's being high Water on the Day of the full or change at *Cape Clear* after 4; and at the *Ushant* about two Hours after, viz. at six, and at the *Lizard* after seven, the *Lizard* and the *Ushant* may properly be called the Chaps of the *British Channel*, between which the Flood sets to the Eastward, along the Coast of *England* and *France*, till it comes to the *Goodwin*, or the *Galloper*, where it meets the Tide before mentioned, which sets to the Southward, along the Coast of *England*, to the *Thames*, where it may not be amiss to observe that these two Tides meeting, contribute very much towards the sending a powerful Tide up the *Thames*, to the City of *London*: and, by the bye, when the natural Course of the Tide is interrupted by a sudden Shift of the Wind; and between this Northern and Southern Tide, driving one back, and the other in, has been known to occasion two high Waters in three or four Hours, which by those who did not consider this natural Cause was looked upon as a Prodigy.

BUT now it may be objected, that this Course of the Flood Tide, East or East-North-East, up the Channel is quite contrary to the Hypothesis of the general Motion of the Tides being from
East

East to West, and consequently of it's being high Water where the Moon is vertical, or any where else in the Meridian.

I answer; this particular direction of any Branch of the Tide doth not at all contradict the general Direction of the whole, a River whose Course is West may supply Canals which may wind North, South, or even East, and yet the River keep it's natural Course; and if the River ebb and flow, the Canals supplied by it would do the same, but not keep exact time with the River, because it would be Flood and the River advanced to some height, before the Flood reach the further part of the Canals, and the more remote the longer time it would require; and I may add, that if it was high Water in the River, just when the Moon is upon the Meridian, she would be far past it, before it could be high Water in the remotest part of those Canals or Ditches, and the Flood would set according to the Course of those Canals that received it, and could not set West up a Canal of a different Position, and as *St George's Channel*, the *British Channel*, &c. is no more in Proportion to the vast Ocean, than these Canals are to a large Navigable River; it will evidently follow, that among those Obstructions, and Confinements, the Flood may set upon any other Point of the Compass as well as West, and may make high Water at any other time, as well as when the Moon is upon the Meridian, and yet no way contradict the general Theory of the Tide before asserted.

FROM this Principle, as confirmed by the strict Observation of Mariners, the following Tide-Table is formed, to shew, at all the places therein mentioned, how many Hours and Minutes the Moon has past the Meridian when it is high Water at the said place, and consequently by knowing the

the time of the Moon's Southing, the time of the Day, that high Water happens at the same place may also be known.

A T I D E - T A B L E.

A		H. M.		
A	Berdeen	0	45	S by W
	Army	1	30	S S W
	St Andrews	2	15	S W by S
	Amsterdam	3	0	S W
	Armentiers	3	0	S W
	Aberwark			
	Abroth	5	15	W S W
	Antwerp	6	0	W.
	Abermoric	6	0	W.
	Archangel	6	0	W.
	Abermorith	6	0	W.
	Amazons River in South A-			
	merica	6	0	W.
	Aldborough	9	45	N W by N
B				
	Beach	0	0	N and S
	Blacktail	0	0	N and S
	Race of Blanquet	0	0	N and S
	Bajador in Barbary	0	0	N and S
	Blacktail Beacon	0	0	N and S
	Beachy	0	45	S by W
	Blacknefs	1	30	S S W
	Bluet	1	30	S S W
	Bell-Isle	1	30	S S W
	Berwick	1	30	S S W
	Bluet without	2	15	S W by S
	Biscay Coast	3	0	S W
	Bourdeaux River Entrance	3	0	S W
VOL II.	U			Buchanefs

	H.	M.	
Buchanefs —————	3	0	S W
Bona Esperance ————	3	0	S W
Brest —————	3	45	S W by W
Bafs without —————	3	45	S W by W
Bridlington —————	3	45	S W by W
Bourdeaux River within —	3	45	S W by W
Brovage without ————	3	45	S W by W
Blois —————	4	30	W S W
Baltimore ————	4	30	W S W
Bree Sound ————	4	30	W S W
Bremen —————	6	0	W.
Blackney —————	6	0	W.
Bristol River ————	6	0	W.
Bristol Key —————	6	45	W by N
Bridgwater —————	7	30	W N W
Cape Blanco —————	9	45	N W by N
Bologne ————	10	30	N N W

C

Cape Cautin in Barbary —	0	0	N and S
Condado ————	0	0	N and S
Chamber of Rye —————	0	45	S by W
Calais without —————	1	30	S S W
Camfere —————	1	30	S S W
Cocquet Island ————	3	0	S W
Cork in Ireland ————	4	30	W S W
Calais ————	4	30	W S W
Cape Clear in Ireland ———	4	30	W S W
Caldy ————	5	15	W by S
Caernarvan Bay —————	5	15	W by S
Cromer ————	6	0	W.
Concalo —————	6	0	W.
Caskets without ————	8	15	N W by W
Cape Serra Leone in Guinea —	8	15	N W by W
Catnefs —————	9	0	N W

Chamber-

	H. M.	
Chambernefs — — — —	9 45	N W by N
Cowes — — — —	10 30	N N W
Caen in the Fofs — — — —	10 30	N N W
Calais Road — — — —	10 30	N N W
Calfhot — — — —	11 15	N by W
Condado — — — —	12 0	N and S

D

Dunkirk — — — —	0 0	N and S
Dover Port — — — —	0 0	N and S
Port Desire in America — — — —	0 0	N and S
Downs in the Road — — — —	2 15	S S W
Dundee — — — —	2 15	S W by S
Denbeigh — — — —	2 15	S W by S
Dort — — — —	3 0	S W
Dunbar — — — —	4 30	W S W
Dungarven — — — —	4 30	W S W
Dartmouth — — — —	5 15	W by S
St Davids Head — — — —	6 0	W.
Dublin in Ireland — — — —	8 15	N W by W
Dungenefs — — — —	9 45	N W by N
Dunnose — — — —	9 45	N W by N
Diepe — — — —	9 45	N W by N
Dunwich — — — —	9 45	N W by N
Dover without — — — —	10 30	N N W

E

Emden — — — —	0 0	N and S
Eider — — — —	0 0	N and S
Elve — — — —	0 0	N and S
Euchuyfen — — — —	0 0	N and S
Edam — — — —	1 30	S S W
Edinburgh — — — —	4 30	W S W
Exwater — — — —	4 30	W S W

	H. M.		
Entrance of the Emes ———	7	30	W N W
Engomonts ——— ———	9	0	N W
F			
Flanders Coast ——— ———	0	0	N and S
Flushing — — — — —	0	45	S by W
Before Fen in the Channel —	1	30	S S W
Finmark Coast — — — —	1	30	S S W
Fountnay without — — —	2	15	S W by S
Flanders without — — — —	3	0	S W
Flambrough Head — — — —	3	0	S W
Fair Isle — — — — —	3	0	S W
Frith — — — — —	4	30	W S W
Falmouth — — — — —	4	30	W S W
Forn — — — — —	5	15	W by S
Foy — — — — —	5	15	W by S
Foulness — — — — —	6	45	W by N
The Fly — — — — —	7	30	W N W
Friesland Coast — — — —	7	30	W N W
Florida in Carolina — — —	7	30	W N W
Fly without — — — — —	8	15	N W by W
Foreland North and South —	9	45	N W by N
Fair Isle — — — — —	11	15	N by W

G

Gibraltar — — — — —	0	0	N and S
Graveling — — — — —	0	0	N and S
Guernsey — — — — —	0	45	S by W
Gooree — — — — —	1	30	S S W
Gravefend — — — — —	1	30	S S W
Galicia — — — — —	3	0	S W
Gascoign — — — — —	3	0	S W
Groyn — — — — —	3	0	S W
Gorend — — — — —	11	15	N by W

Hever

H				H. M.		
Hever	—	—	—	0	0	N and S
Hampton Key	—	—	—	0	0	N and S
Hern	—	—	—	0	0	N and S
Holy Island	—	—	—	1	30	S S W
Hartlepool	—	—	—	3	0	S W
Huntcliff-foot	—	—	—	3	45	S W by W
Humber without	—	—	—	4	30	W S W
Holmes	—	—	—	6	0	W.
Hull	—	—	—	6	0	W.
Hamburgh	—	—	—	6	0	W.
Hague	—	—	—	8	15	N W by W
Harlem	—	—	—	9	0	N W
Home-head	—	—	—	9	0	N W
Havre de Grace	—	—	—	9	0	N W
Harwich Banks without	—	—	—	10	30	N N W
St Helens	—	—	—	10	30	N N W
Harwich within	—	—	—	11	15	N by W
I						
Jutland Isles	—	—	—	0	0	N and S
Ireland West Coast	—	—	—	3	0	S W
Ireland South Coast	—	—	—	5	15	W by S
John de Luce	—	—	—	10	30	N N W
K						
Kentish Knock	—	—	—	0	0	N and S
Killiars	—	—	—	3	0	S W
Kingfale in Ireland	—	—	—	4	30	W S W
Kilduyn	—	—	—	7	30	W N W
Kildive	—	—	—	9	0	N W
L						
Lisbon	—	—	—	2	15	S W by S
St Lucas	—	—	—	2	15	S W by S
London	—	—	—	3	0	S W
Leith	—	—	—	4	30	W S W
U 3						Lawre

	H.	M.	
Lawrenefs — — — —	5	30	W S W
Lynn without — — — —	4	15	W by S
Lundy Island — — — —	5	15	W by S
Lynn — — — —	6	0	W.
Lanion — — — —	6	45	W by N
Land's-end of England — —	7	30	W N W
Lizard — — — —	7	30	W N W
Lambay — — — —	8	15	N W by W
Lewstoft — — — —	9	45	N W by N
Lenow — — — —	9	45	N W by N

M

Maes within — — — —	0	45	S by W
Malden — — — —	0	45	S by W
St Mark — — — —	2	15	S W by S
St Matthew's point — — —	3	45	S W by W
Moufe-hole — — — —	4	30	W S W
Mounts Bay — — — —	4	30	W S W
Millford — — — —	5	15	W by S
Moonlefs — — — —	5	15	W by S
St Maloes — — — —	5	15	W by S
Magnes Sound — — — —	8	15	N W by W
Macknel's Castle — — — —	8	15	N W by W
Isle of Man — — — —	9	0	N W
Marget Road — — — —	11	15	N by W

N

Newport Isle of Wight — —	0	0	N and S
Nore — — — —	0	0	N and S
North Cape — — — —	3	0	S W
Nantz River without — — —	3	0	S W
Newcastle — — — —	5	15	W by S
St Nicholas Ruffia — — —	6	45	W by N
Needles — — — —	9	45	N W by N
Normandy Coast — — — —	10	30	N N W
Naze — — — —	11	15	N by W

Orkneys

O				H. M.		
Orkneys	—	—	—	3	0	S W
Orwell	—	—	—	9	0	N W
Orfordness	—	—	—	9	45	N W by N
Orfordness without the Banks	—	—	—	10	30	N N W
Orfordness within the Sands	—	—	—	11	15	N by W

P						
Portsmouth	—	—	—	0	0	N and S
Poictou South Coast	—	—	—	3	0	S W
Pens	—	—	—	3	0	S W
Porthus	—	—	—	3	0	S W
Portugal Coast	—	—	—	3	0	S W
St Pauls in the Haven	—	—	—	6	0	W.
Plymouth	—	—	—	6	0	W.
Podesemsk in Russia	—	—	—	6	15	W by N
Thwart of Plymouth	—	—	—	7	30	W N W
Portland	—	—	—	8	15	N W by W
Peterport	—	—	—	8	15	N W by W
Picardy Coast	—	—	—	10	30	N N W

Q						
Queenborough	—	—	—	0	0	N and S
Quebec in Canada	—	—	—	6	0	W.

R						
Rebdan	—	—	—	0	45	S by W
Rocheſter	—	—	—	0	45	S by W
Rumney	—	—	—	1	30	S S W
Ramkins	—	—	—	1	30	S S W
Robin Hoods Bay	—	—	—	3	0	S W
Rotterdam	—	—	—	3	0	S W
Rovain	—	—	—	3	45	S W by W
Rochel without	—	—	—	3	45	S W by W
Roan River within	—	—	—	3	45	S W by W
Ramſey	—	—	—	5	15	W by S

U 4

Rye

				H. M.	
Rye	—	—	—	11 15	N by W
Rhodes	—	—	—	11 15	N by W
S					
Shoore	—	—	—	0 0	N and S
Along the Swin	—	—	—	0 0	N and S
Sheerness	—	—	—	0 0	N and S
Sleeve	—	—	—	0 0	N and S
Southampton	—	—	—	0 0	N and S
Spits	—	—	—	0 0	N and S
Shotland	—	—	—	3 0	S W
Scilly	—	—	—	3 45	S W by W
Scarborough	—	—	—	3 45	S W by W
Sound	—	—	—	3 45	S W by W
Staples	—	—	—	3 45	S W by W
Severn	—	—	—	4 30	W S W
Seven Isles	—	—	—	4 30	W S W
Stockton	—	—	—	5 15	W by S
Spurn	—	—	—	5 15	W by S
Salcomb	—	—	—	6 0	W.
Start	—	—	—	6 45	W by N
Sedmouth	—	—	—	6 45	W by N
Selberg	—	—	—	9 0	N W
Seven Cliffs	—	—	—	9 0	N W
Shoram	—	—	—	9 45	N W by N
Seyn-Head	—	—	—	10 30	N N W
Senegal	—	—	—	10 30	N N W
T					
Terveere within	—	—	—	0 45	S by W
Thanet Island	—	—	—	1 30	S S W
Terveere without	—	—	—	1 30	S S W
Tinmouth	—	—	—	3 0	S W
Tees Mouth	—	—	—	3 0	S W
Teneriff	—	—	—	3 0	S W
Torbay	—	—	—	5 15	W by S

Texel

					H.M.	
Texel	—	—	—	—	7 30	W N W
Tergon	—	—	—	—	9 45	N W by N
U						
Urk	—	—	—	—	0 0	N and S
Ufe	—	—	—	—	3 0	S W
Vourd	—	—	—	—	4 30	W S W
Ufhant without	—	—	—	—	6 0	W.
St Vallery	—	—	—	—	10 30	N N W
W						
Ile of Wight	—	—	—	—	0 0	N and S
Winchelfea	—	—	—	—	0 45	S by W
Weilands	—	—	—	—	1 30	S S W
Whitby	—	—	—	—	3 0	S W
Waterford in Ireland	—	—	—	—	4 30	W S W
Weymouth	—	—	—	—	6 0	W.
Wells	—	—	—	—	6 0	W.
Weymouth Key	—	—	—	—	6 45	W by N
Off the Isle of Wight	—	—	—	—	8 15	N W by W
Winterton	—	—	—	—	9 0	N W
Y						
Youghal in Ireland	—	—	—	—	4 30	W S W
Yarme	—	—	—	—	6 45	W by N
Yarmouth Road	—	—	—	—	8 15	N W by W
Yarmouth Pier	—	—	—	—	9 0	N W
Yarmouth Town	—	—	—	—	9 45	N W by N
Z						
Zealand Coast	—	—	—	—	1 30	S S W
Zuric Sea	—	—	—	—	3 0	S W

IN this Tide-Table, the first Column contains the Names of the Sea Ports; the second is the Hour and Minute of high Water, or the Days of the full and change at the Port, against which it stands,

stands, or the Hour and Minute to be added to the time of the Moon's southing, to find the time of high Water at the said Port. The third Column shews upon what point of the Compass the Moon makes full Sea, at the place against which it stands.

E X A M P L E.

I would know upon what Point of the Compass the Moon is, and what is the Hour of the Day, when it is high Water at *London Bridge*, on the Day of the full or change.

LOOK for *London* in the Tide-Table, and against it you find in the second Column, 3 Hours 00 Minutes, and in the third Column SW; which shews that a South-West Moon makes high Water at *London Bridge*, and that on the Days of the Full and Change it is high Water at *London Bridge* at 3 o'Clock. But for any other age of the Moon, add the Hour and Minute which stands against the Port, proposed to the Hour and Minute of the Moon's southing, their sum (abating 12 if it exceeds) is the time of high Water next morning, &c. of which hereafter.

Note. It is high Water when the Moon is upon both the opposite Points of the Compass; as if a South-West Moon makes high Water at *London Bridge*, a North-East Moon will do the same; and if it is high Water at 3 in the Afternoon, it will be high Water at the same place at (near) 3 the next Morning also.

BUT as finding the time of high Water depends upon the Moon's southing; and that is to be found by the Golden Number, and the Epact, it is necessary first to know how to find them as follows.

1. To find the Golden Number.

DIVIDE the Year of our Lord by 19, and the remainder with 1 added to it, is the Golden Number.

Example. I desire to know what is the Golden Number for the Year 1734.

19)1734(91
 24
 Remainder ——— 5
 To which add ——— 1
 The Sum is the Golden Number ——— 6

2. To find the Epact.

MULTIPLY the Golden Number by 11, divide the Product by 30, the Remainder is the Epact. Or add 11 to the Epact of any one Year it gives the Epact for the Year following, casting away 30, if the Sum exceeds 30.

Example. what is the Epact for the Year 1733.

The Golden Number is	—	5
Multiply by	— — — — —	<u>11</u>
The Product is	— — — — —	55
From whence take	— — — — —	<u>30</u>
The Remainder is the Epact	—	<u>25</u>
The Epact for 1733 is	— — — — —	25
To which add	— — — — —	<u>11</u>
The Sum is	— — — — —	36
Cast away	— — — — —	<u>30</u>
Remains the Epact for 1734, viz.	—	<u>6</u>

3. To

3. To find the Moon's Age.

ADD the Epact, the Day of the Month, and the Number of the Month from *March* (accounting *March* 1, *April* 2, &c.) altogether the Sum (casting away 30, if it exceed 30) is the Moon's Age.

Example. How many Days old is the Moon *June* 16 1733.

The Epact in 1733 is	—	—	25
<i>June</i> is the 4th from <i>March</i>	—		4
The 16th Day	—	—	16
The Sum	—	—	45
Cast away	—	—	30
Remains the Moon's Age	—		15

4. To find what Day the Moon Changes.

ADD the Epact, and the Number of Months from *March* together, and subtract the Sum from 30, but if the Sum amount to 30, or more, subtract it from 60, the Remainder is the Day of the Moon's changing.

Example. I desire to know what Day of *June* in the Year 1733, the Moon will change.

THE Number of the Month from *March* Inclusive is 4, the Epact is 25; the two added together make 29, which taken from 30 there remains 1, which shews that the Moon changes *June* 1, 1733.

5. To find the Time of the Moons southing.

MULTIPLY the Moon's Age by 4, and divide the Product by 5, the Quotient is the Hour
to

to which for every one that remains, add 12 Minutes, it gives the time of the Moon's southing.

Example. I desire to know what time the Moon souths, *June 7, 1733.* The Moon will be found by the Rule above, to be 6 Days old, on the 7th of *June*; multiply 6 by 4, it produces 24, which divided by 5 the Quotient is 4, and 4 remains, which shews that the Moon souths at 48 Minutes after 4 o'Clock that Day.

BUT there is another Method for finding the Moon's southing, which I have seen in a Book in *English*. The Author entitles it, *How to know the time of the Moon's coming to South, only by a sight of the Moon at any time of the Day or Night*; and the Method being so easy in Practice, and so mathematically true, as well as familiar to all Capacities; I thought it was not proper to omit it.

THIS way of finding the Moon's southing, is grounded upon this known and undeniable Truth, that the new Moon, or when she is with the Sun, souths at Noon; and consequently the Moon when at the full, or opposite to the Sun, souths at Midnight; when she is half full, or at what is called the Quarters, she souths at six o'Clock; in which we may observe, that when the West half of the Moon is light, she souths at six in the Evening; and when the East half is light, she souths at six in the Morning, when the light part of the Moon is separated from the dark part by a strait Line, or Diameter, drawn through her Center divides her into two equal parts.

THIS being premised, and there being, as above observed, twelve Hours difference, between the time of her southing at the Change, or new Moon, and that at the full Moon, the Author supposes the visible Semi-Surface of the Moon to be divided into twelve parts, equal parts upon the
2
globular

globular Surface of the Moon, but unequal as they appear at the Earth (nearly) like the orthographic projection, and these Circles to be marked 1, 2, 3, 4, &c. to 12 (*See Fig. A, Plate VIII.*) reckoning from the Primitive on the West side of the Moon, coming to 6 in the Diameter, or Line, which crosses the Center of the Moon, and divides her in two equal parts, and ending at 12 on the East part of the Primitive: This done when you see the Moon partly illuminated, compare her with the Figure, and consider to which of the Circles, the light part may be imagined to extend, and the number or Figure upon that Circle, is the time of the Moon's southing.

Example. Suppose the shaded part of the Moon N 5 S W was enlightened, it shews that the Moon souths that Day at 5 o'Clock; and because the light part is on the West Side, the Moon souths at five in the Afternoon; but if all that part of the Moon had been light, that is light in the Figure viz. N E S 5, the Number 5 upon the Arch, would show that she souths at five o'Clock, but the light part being on the East Side, shews that she souths at five in the Morning.

6. *To find the Time of high Water.*

TO the Hour and Minute of the Moon's southing, add the Hour and Minute found in the Tide-Table against the Port proposed, the Sum is the time of high Water at the said Port, but if it exceeds 12 Hours, cast away 12, and the Remainder is the time of high Water next Morning.

Example. I desire to know the time of high Water at London Bridge on the 7 of June 1733 above mentioned.

The

	H. M.
The Moon souths that Day at — —	4 48
Time against <i>London</i> in the Tide Table	3 00

Sum is high Water at <i>London</i> Bridge	7 48

THUS much I thought was necessary to be inserted, not only as to the Theory of the Tides, and the original Cause of the flowing and ebbing of the Sea in general, but with respect to the actual Calculation of their Motions, and the determining the times of high Water at any place proposed in particular, which being done, and before I quit this Subject of the Fluctuation of the Water in different parts of the World, it may not be amiss to observe, that some whose over Curiosity have led them into Extreams, and they allowing the abovementioned Hypothesis of the Tide, to be agreeable to both Reason and Experience, as well as to the Principles of Philosophy, would strain it beyond it's bounds, and from some Principle of the same Nature, would account for the overflowing of the River *Nile*; but as that proceeds from a quite different Cause from that of the ebbing and flowing of the Sea, I presume it will be no unnecessary Digression to give the following true and natural Reasons for that too, (and the rather because it has formerly been looked upon as something supernatural, or as a sort of a Prodigy) that the industrious Enquirer may be informed on one hand, as well as their Mistakes may be rectified who would draw Inferences from wrong Foundations on the other.

Of the Natural Cause of the overflowing of the River Nile in Egypt.

TO go so far back towards the original, as to give a Natural or Philosophical Reason for the excessive Rains, at certain Seasons of the Year, near or between the Tropics, would take up more time and room, than this Treatise of General Geography will admit of; but Experience, grounded upon the most natural and philosophical Reasons, convinces us that there are almost perpetual Rains from *April* or *May*, till *July* or *August*, in places lying near or within the northern Tropic; and this being proved and allowed, it will not be difficult to account for the Annual overflowing of the River *Nile*, which rises in about fourteen or fifteen Degrees of North Latitude, or about nine Degrees to the Southward, of the the Tropic of *Cancer*, and in it's Course to the Northward, it crosses the said Tropic before it comes to the *Mediterranean*, or *Levant*, which lies in above thirty Degrees of North Latitude, and as it is so large a River, and runs through the low Grounds of *Egypt*, it must be supplied by a great Confluence of Rivers, and receive all those heavy Rains that fall in, or near it's passage, and having no way to disgorge it self, till it empties it self into the *Levant*, it is no more difficult to account for it's overflowing the low Lands of *Egypt*, in it's passage through it than it is to account for a Land flood, after a sudden heavy Rain in *England*, or in any other place; this Consideration makes the overflowing of the *Nile*, so far from being a Wonder, that it would be a much greater Wonder, and more difficult or rather impossible to be accounted for, if all these excessives and durable Rains that fall in the *Nile*, and that from the adjacent Country descend

descend into it, could vent themselves without some visible way of being conveyed to the Sea, and the River *Nile* not be affected with it; but seeing the vast confluence of Water, proceeding from those excessive Rains, has no other vent but by the *Nile*, it will necessarily follow, that the *Nile* must overflow it's bounds at those rainy Seasons, and yet it's Inundation has no dependance upon the Moon, nor upon the natural Causes, above assigned, for the regular flowing and ebbing of the Sea.





C H A P. XXXVIII.

Of the Bearing of Places, or the Points they lie in, from one another

PROPOSITION I.

To know in each Place the four Cardinal Points, and the intermediate ones.

THIS is the most necessary Problem in the whole Art of Navigation, for without it there is no directing a Ship; and the want of this very thing hindered the Antients from sailing far. And herein is the chief Difference between the antient and modern sailing; for the Antients had no certain Method to find the North and South Points at any time; and therefore durst not trust themselves into the wide Ocean; but only coasted along the Shores, that they might by some Signs know where they were.

THE Antients had two ways which are servicable to the Moderns, for finding the North and South (or a meridian Line) from which the other Points are easily known; 1. By the Stars at Night, particularly the *Little Bear*, and the Star in it's Tail, called the *Pole-Star*; which was much famed with Antiquity, and served to show them the North, and thereby all the other Points; for turning their Face to it, the East was on the right, and the West on the left, and the South behind; and they had a Circle with the Points on it, and bringing the

the North and South Point, to the meridian Line, the other Points were seen at once.

BUT by Day they used the Sun rising or setting, as we shewed in *Chap. xxviii.*

2. ANOTHER Method they had was by knowing the Situation of the Shores, and of one Promontory from another; for when one Point was thus known, either from the Maps, or by Observation and Experience, they could in sailing find the rest; but then they could not go far from the Shores, which directed them as to the Points: for they could not at all times use the Sun and Stars for that end.

3. A third Method they used, was by observing the Points they had run in; for knowing how they first directed the Ship, and how much they turned again, their Course from that Point, they knew the other Points.

FROM whence the Reason appears of their imperfect and dangerous sailing; viz. their not knowing the Points in the wide Ocean, so as to tell how to steer.

THIS third Method by observing the Ship's Course, is of no use when the Ship is turned to a great many Points by the raging Sea and Waves.

SO far of their Method of finding the Meridian Line, which was so imperfect, that they durst never trust themselves in the vast Ocean, and so never knew *America.*

WE have now a plain and easy Method of finding the North and South Points, and all the rest from them, by the help of that wonderful Property which the Load-stone, and all Needles of Iron touched with it's Poles, or lying long near it, or even lying long in the Meridian Line, are found to have; which is, that they turn to the North and South, if not hindered; the Load-stone

having two opposite Poles, of which the one turns always to the North, the other to the South, and the other Parts to the other Points ; but the North and South Pole of it is only considered : and the same Property it communicates to a Rod of massy Iron, or a small Needle, but in a contrary way ; for the end of the Needle drawn on the North Pole of the Load-stone, turns to the South ; and that end which is applied or rubbed on the South Pole of the Load-stone, turns to the North, and is called the North Pole of the Needle : which wonderful Property of the Load-stone was unknown to the Antients, though, which is strange, they were acquainted with it's other Property of drawing Iron to it.

T H U S the North and South Points may be easily found by hanging the Load-stone, which is carried to Sea with them, by a Thread, that it may turn itself easily to the North and South ; but 'tis better done by applying a Needle to the North Pole of the Load-stone : for recovering it's Virtue, and drilling a Cap in it's middle, and laying it on the Top of a sharp brass Pin, so that it may move freely, it will, when it rests, show the North and South.

P R O P O S I T I O N II.

To make the Sea Compass.

D I V I D E a Circle drawn on a Chart into thirty two Points, and chuse one of them for the North, mark it with the *Flower-de-Luce*, and count the other Points from it, which are to be marked on it.

T H E N let the magnetic Needle be fixed under the Circle drawn on the Chart, so as the middle of the Needle may be under the Center, and the North Pole on the Chart may be fixed to the North

End of the Needle ; then placing the Needle and Chart, fixed to it above, on the brass Pin, that it may move freely, it will turn about, 'till the Needle lie in, or near, the Meridian Line. By the help of this Compass they can go thro' the vast Ocean to the most remote Parts, being guided by the Direction of the Needle. We said *near* the Meridian Line, for it doth not point exactly to it ; for which see *Prop. vi*, following.

PROPOSITION III.

Infinite Points may be drawn on the Compass ; Seamen count sixteen in small Voyages, and thirty two in greater, but sixty four in the greatest.

OF this we have spoke in *Chap. xx.* whence may be had an accurate Explication. The *Portuguese* call the Points *Rhombs*.

PROPOSITION IV.

The magnetic Needle (as also the Poles of the Loadstone itself) points direct North only in a few Places, but in most Places declines a little to the East or West, and that unequally ; and so doth not point due North and South.

FOR at one of the Isles of the *Azores*, or *Flandrian* Isles, called *el Corvo*, there is no Declination from the Meridian, and the Needle lies exactly in it ; and 'tis so in some others, tho' not all Parts of that Meridian. In Places situated eastward from this Island to the Promontory of *Africa*, called *Cabo das Agulhas* (not far from the Cape of *Good-Hope*) the Needle declines eastward unequally ; so that to the Isles of *Tristan de Cunha*, and seventy Degrees further, the Declination increases so as to

be about thirteen Degrees there ; and from thence it decreases all the way to Places near the Promontory of *das Agulhas*, in which there is again no Declination. And from that Place towards *India* the Declination begins to the westward. The Declination at *Hamburg* is nine Degrees, at *Amsterdam* about five Degrees, tho' formerly it was more,

OBSERVATIONS testify, that the Declination is not always the same, but changes in process of time. At *London* in 1580 it was found to be eleven Degrees fifteen Minutes ; but in the Year 1622 it was only six Degrees thirteen Minutes ; and in 1634 it was four Degrees six Minutes ; Observations being made, both with old and new Needles. At *Paris* in 1640 it was three Degrees, and in 1610 it was eight Degrees, and the same is observed in other Places.

BEFORE the Variation of the Compass was observed to alter, or be different at the same place at different Times ; it was supposed, by some, that the general Position of the Needle, towards the North and South, and yet not exactly to these points in all Places, or rather in but few places, was occasioned by the *Excavations of some parts of this terraqueous Globe* ; or by *magnetical Veins, collaterally respecting the Needle, &c.* But this Opinion was soon exploded, when the Variation of Variation was discovered ; for if the position of the Compass (whether directly North and South, or with some deviation from the Meridian, which is called the Variation) had been always the same in the same place, there would be room to believe that That position of the Compass, was occasioned by those Excavations or Adamantine Rocks, &c. but as we find the Variation alters, there must be some other Reasons assigned for the different Position or direction of the magnetical Needle. But as a Principle

to go upon, I shall rank some authentic Observations, of the Variation of the Compass in their proper Order, with the time when they were taken, and from thence prove the probability of the Variation of the Compass (however irregular it may seem) being reducible to a regular Motion.

				D.	M.	
1580	At Limehouse, London	—	—	11	17	} East
1622	At London	—	—	6	13	
1634	At London	—	—	4	6	
1640	At Paris	—	—	3	0	
1666	At London	—	—	0	34	} West
1670	At Battersey near London	—	—	2	6	
1701	In the Channel	—	—	7	30	

A N D to this may be added, that at the writing here of *Anno* 1734, the Variation at *London*, is more than one Point westerly.

I have inserted this Catalogue of Observations of the Variation of the Compass, to prove that the Variation alters, and not only so, but in a sort of a regular Manner too, as having been above eleven Degrees easterly in the Year 1580, and then gradually decreasing to six, four, three, &c. and doubtless some time between the Year 1640, and the Year 1666 there was no Variation; because in 1666 the Variation was westerly, increasing to two, seven, and now above twelve Degrees; how far it may advance further that way, before it come at it's Period, Time only can determine; nor are we certain what was it's utmost limits easterly before the aforesaid Year 1580, or when it was at those limits; but certain it is that this regular Motion of the Variation, as observed, corroborates, or rather confirms, that excellent Theory

of the celebrated Dr *Halley* as to magnetical Poles, &c. hereunto subjoined (e).

PRO-

(e) The learned Dr *Halley* having made a Collection of the exactest Observations he could procure, and carefully compared and considered them together; thence deduces the following Conclusions, concerning the Variation of the *magnetical Needle*. See *Philos. Transact.* No. 148.

1. That in the Year 1683, the Variation was to the West over all *Europe*; but more in the eastern Parts than the western.

2. That on the Coast of *America*, about *Virginia*, *New-England*, and *New-found-land*, the Variation is likewise westerly; and increases all the way to those that go northerly along the Coast: so as to amount to above twenty Degrees at *New-found-land*, nearly thirty in *Hudson's Strieghts*, and fifty seven in *Baffin's Bay*. But it diminishes to those that sail eastward from this Coast. And from these two Observations it seems to follow, that *there ought to be an easterly Variation, or at least not a westerly one, somewhere between Europe and the North Part of America*; and this we may conjecture happens about the most easterly of the *Tercera Islands*.

3. That on the Coast of *Brazil* there is an easterly Variation which increases considerably in sailing to the southward; so as to be twelve Degrees at *Cape Frio*, and twenty and a half o-

ver against the *Plate River*: and from thence sailing southwesterly to the Strieghts of *Magellan*, it decreases to seventeen Degrees; and at the West Entrance of those Strieghts it is but fourteen.

4. That to the eastward of *Brazil*, properly so called, this easterly Variation decreases, so as to be very small at the Islands of *St Helen*, and *Ascension*; and to vanish about eighteen Degrees of Longitude West from the Cape of *Good-Hope*, where the Needle points due North and South.

5. That to the eastward of the foresaid Places, a westward Variation begins; which obtains in the whole *Indian Ocean*; and amounts to eighteen Degrees under the very Equator; about the Meridian of the northern Part of *Madagascar*: and near the same Meridian in thirty nine Degrees of South Latitude it amounts to twenty seven Degrees and a half. From thence easterly the West Variation decreases gradually, so as scarce to exceed eight Degrees at *Cape Comorin*, and not above three upon the Coast of *Java*; but about the *Molucca Islands* there is no Variation at all. The Case is likewise the same, a little to the westward of *Van Dieman's Land*.

6. That to the eastward of the *Molucca's* and *Van Dieman's Land*, in South Latitude, there

PROPOSITION V.

To find the Declination of the Needle from the North in any Place.

FIND a Meridian Line by the Heavens, as we shew'd by several ways in Chap. xx, and by that may

is found another easterly Variation, tho' less than the former both in Extent and Degree: for at the Island of *Rotterdam* it is sensibly less than upon the East Coast of *New Guinea*. And to observe the Proportion wherein it decreases, we may reasonably suspect that it vanishes about twenty Degrees farther to the East, or about two hundred and twenty five Degrees East Longitude from *London*, in twenty Degrees South Latitude; and that there a westerly Variation begins.

7. That the Variations observed at *Baldivia*, and the West Entrance of the Streights of *Magellan*, shew that the East Variation, explained in the third Observation, decreases apace, and cannot reasonably extend many Degrees into the South Sea, from the Coast of *Peru* and *Chili*; leaving room for a small westerly Variation, in that Tract of the unknown World, betwixt *Chili* and *New Zeland*, and betwixt *Hound's Island* and *Peru*.

8. That in sailing North-West from *St Helen's Island* by *Ascension*, as far as the Equators, the East Variation continues

very small, or as it were constantly the same. So that in this part of the World, the Tract of the Ocean where no Variation appears, is not extended in the Plane of any Meridian, but rather North-West.

9. That in the Entrance of *Hudson's Streights*, and the Mouth of the *Plate River*, tho' these are nearly under the same Meridian, yet in the one the Needle varies twenty nine Degrees and a half to the West; and twenty and a half to the East in the other. Whence plainly appears the Impossibility of accounting for these Variations, by the Supposition of two magnetical Poles, and an Axis inclined to the Axis of the Earth: from whence it should follow, that under the same Meridian the Variation should in all Places be the same way.

In order to explain these Phenomena, Dr *Halley* sagaciously supposes the Globe of the Earth to be a great Magnet, having four magnetical Poles; two near the North, and as many near the South Pole of the Earth; and that the Needle is governed by each of these Poles, whilst the Virtue of the nearest

may the Declination of the Needle readily appear; but for Sea-mens Use the following Proposition will show it more readily.

P R O-

nearest Pole predominates over that of the more remote.

But many Particulars being required to determine the Places of these Poles with exactness; the Doctor determines them thus by conjecture. He places the North magnetic Pole nearest to us, in or near the Meridian of the Land's End of *England*; and not above seven Degrees from the North Pole. By this Pole the Variations in all *Europe*, and *Tartary*, and the North Sea are principally govern'd; tho' it is somewhat affected by that other northern magnetic Pole, situated in a Meridian passing thro' the middle of *California*, and about fifteen Degrees from the North Pole of the World. To this the Needle has chiefly respect in all North *America*, and in the two Oceans, on either side thereof, from the *Azores* westward, up to *Japan*, and beyond.

The two southern magnetical Poles are somewhat farther distant from the South Pole of the World; the one, being about sixteen Degrees from it, is in a Meridian twenty Degrees to the westward of *Magellan's* Streights, or ninety five Degrees West from *London*. This commands the Needle in all South *America*, in the *Pacific*, and the greatest Part of the *Ethiopic* Ocean.

The fourth Pole seems to have the greatest Virtue, and largest Dominion, being furthest distant from the Pole of the World, viz. about twenty Degrees; in a Meridian passing thro' *New Holland*, and the *Celebes*, about one hundred and twenty Degrees from *London*. This Pole predominates in the South of *Africa*, in *Arabia*, and the *Red-Sea*; in *Persia*, *India*, and its Islands, and all over the *Indian* Ocean from the Cape of *Good-Hope* eastwards, to the middle of the great South Sea, that divides *Asia* from *America*.

It remains to be shown how the Conclusions set down are deduced from this Hypothesis. And that the whole may be the better understood; either a Globe or Map should be used, whereon the four magnetical Poles are to be placed in the Situations above described.

And first, it is plain, that our *European* magnetical North Pole being in the Meridian of the Land's End of *England*, all Places more easterly than that, will have it on the West Side of their Meridian, and consequently the Needle respecting it, with it's northern Point, will have a westerly Variation; which will still increase in sailing eastwards up to some Meridian of *Russia*, where it will be greatest; and from thence decrease again. Thus at *Brest* the Variation is but one Degree

PROPOSITION VI.

To explain the Method which Seamen use for correcting their Sea-Compass; and to find the Declination of the Needle.

KNOWING the Declination of the Needle in the Place where their Compass is made, they remove

gree and three Quarters, at *London* four Degrees and a half; but at *Dantzic* seven Degrees West. Westward of the Meridians of the Land's End, the Needle ought to have an easterly Variation; but that by approaching the *American* North Pole (which lies on the West Side of the Meridian, and seems to have a greater Force) it is thereby drawn to the westward; so as to balance the Direction given by the *European* Pole, and make a small West Variation in the Meridian of the Land's End itself. Yet the Doctor supposes, that about the Meridian of the Isle of *Tercera*, our nearest Pole may so far prevail as to give the Needle a small turn to the East, tho' it be but a little Space; the Counter-balance of these two Poles permitting no considerable Variation, in all the eastern Parts of the *Atlantic* Ocean, near upon the West Coasts of *England*, and *Ireland*, *France*, *Spain*, and *Barbary*.

But to the westward of the *Azores*, the Power of the *American* Pole overcoming that of the *European*, the Needle is chiefly affected by that, and

turns still more and more towards it, and as you approach it. Whence it happens, that on the Coast of *Virginia*, *New-England*, *New-found-land*, and in *Hudson's* Streights, the Variation is westward; that it decreases as you go from thence towards *Europe*; and that it is less in *Virginia*, and *New-England*, than in *New-found-land* and *Hudson's* Streights.

This westerly Variation again decreases as you pass over *North America*; and about the Meridian of the middle of *California* the Needle again points due North; and from thence westward to *Yedzo* and *Japan*, doubtless the Variation is easterly; and half cross the *Pacific* Sea not less than fifteen Degrees. And this is proposed as a Trial of the Hypothesis, that the whole may be examined thereby. And this East Variation is supposed to extend over *Japan*, *Yedzo*, *East Tartary*, and Part of *China*, 'till it meet with the westerly, which is governed by the *European* North Pole.

The Effect is much the same towards the south Pole, only here the South Point of the Needle

move the *Flower-de-Luce* so many Degrees from the North End of the Needle eastward, if the Declination

Needle is attracted. Hence it will follow that the Variation on the Coast of *Brasil*, at the *River Plata*, and so on to the *Streights of Magellan*, should be easterly; if we suppose a Pole situate about twenty Degrees more westerly than the *Streights of Magellan*. And this easterly Variation extends eastward over the greatest Part of the *Ethiopic Sea*, 'till it is counterpoised by the Virtue of the other southern Pole; as it is about the middle betwixt the Cape of *Good-Hope*, and the Isles of *Tristan d'Acunha*.

From thence eastward the *Asiatic* South Pole prevailing, and the South Point of the Needle being attracted thereby, there arises a West Variation very large, both in Quantity and Extent; on account of the great Distance of this magnetic Pole from the Pole of the World. Hence in all the *Indian Ocean*, as far as *New-Holland*, and beyond, there is constantly a West Variation; so that under the Equator itself, it amounts to eighteen Degrees, where it is greatest. About the Meridian of the Island *Celebes*, being likewise that of this Pole, the westerly Variation ceases, and an easterly begins, which reaches according to the Hypothesis, to the middle of the South Sea, between *New-Zeeland*, and *Chili*; leaving room for a small West Variation, governed by the *Ameri-*

can South Pole, which, by the sixth and seventh Observations, was shewed to be in the *Pacific Ocean*.

Hitherto the Consideration of the Variation has been simple: whilst no more than two magnetic Poles were regarded at once; but under the Equator, and thro' all the *Torrid Zone*, respect must be had to all four Poles; and their Positions must be well considered; otherwise it will not be easy to determine what the Variations should be: the nearest Pole proving always the strongest; yet not so but that it is sometimes balanced by the united force of two more remote; a notable Instance whereof we have in our eighth Observation; where we find that in sailing from *St Helen's*, by the Island of *Ascension*, to the Equator, on a North-West Course, the Variation is very little easterly, and in that whole Tract unalterable; because the South *American* Pole (which lies considerably nearest to the foresaid Places) requiring a great easterly Variation, is balanced by the contrary Attraction of the North *American* and *Asiatic* Pole; each whereof singly, is in these Parts weaker than the *American* South Pole: and upon the North West Course the Distance from this latter is very little varied. And as you recede from the *Asiatic* Pole, the Balance is still preserved by the Access towards the North

clination be to the West, and contrariwise if to the East.

Y E T

North *American* Pole. And little or no regard need here be had to the *European* North Pole; it's Meridian being a little removed from the Meridians of these Places; and of itself requiring the same Variations that we here find. And after the same manner we might reason upon the other Variations thro' the *Torrid Zone*.

And thus by a simple Hypothesis Dr *Halley* has, with great Ingenuity and Probability solved the Phænomena of the Variation; tho' there still remains a great Difficulty or two to be considered. For it is new and strange to attribute more than two Poles to a Magnet; whereas this Hypothesis attributes four to the Earth. And again, the Variation is found different at different Times in the same Place; which can by no means proceed upon the Supposition of a fixed unvaried Situation of the magnetical Poles. The Doctor therefore deterred by these Considerations gave over his Thoughts upon the Subject for several Years, but at length renewed them; and with an adventurous indeed, but probable, Hypothesis, happily solved the Difficulties. For, by comparing together the Observations made upon the Variation of the Variation he shewed first, that whatever these Differences arise from it must move from East to West.

2. That this motion is not de-

sultory, but gradual and continued; because the Declination of the Needle changes gradually and regularly. 3. That it must needs be something great whose Force can produce one and the same concurrent Effect in such very distant Regions of the Earth. 4. That as we know of no Fluids that have the least magnetical Virtue, it is not probable that this Variation should proceed from the Motion of any Fluid lodged in the Cavities of the Earth. 5. That whatever Body it was, it could only move circularly round the Center of the Earth, without changing the Center of Gravity of the *Terraqueous* Globe, and thus occasioning great Changes on it's Surface; such as strange Reflexes of the Sea, and Inundations of Land, of which there appears no Signs in History. From all which it follows, that a certain large solid Body, contained within, and every way separated from the Earth (as having it's own proper Motion) and being included, like a Kernel in it's Shell, revolves circularly from East to West, as the exterior Earth revolves the contrary way in the diurnal Motion. Whence it is easy to explain the Supposition of the four magnetical Poles above attributed to the Earth, by allowing two to the nucleus, and two to the exterior Earth. And as the two former perpetually alter their Situation by their circular

YET because the Declination varies according to the Place they come to, the Chart must be made so as the *Flower* may turn less or more from the North End of the Needle, which must be done according as they find the Declination to be.

TO find which most Seamen do thus: They find in what Point the Sun rises, or sets, and tho' in the time between both, they have gone some way, yet the Declination will not alter much in so small a Distance.

IF the East and West Line, or any Point found, be the same with that, the Compass shows there is no Variation; but if it be a Point farther from, or nearer to, the North than that which the Compass shows, then there is some Variation to the West, or East. The Quantity of the Declination is thus known: Take the Differences between the North

circular Motion, their Virtue compared with the exterior Poles, must be different at different Times; and consequently the Variation of the Needle will perpetually change.

The Doctor attributes to the Nucleus an *European* North Pole, and an *American* South one; on account of the Variation of the Variations observed near these Places, as being much greater than those found near the two other Poles. And he conjectures that these Poles will finish their Revolution in about seven hundred Years; and after that time the same Situation the Poles obtain again as at present; and consequently that the Variations will be the same again over all the Globe. So that it requires several Ages before this Theory can be thoroughly adjusted.

He assigns this probable Cause of the circular Revolution of the Nucleus; that the diurnal Motion being impressed from without, was not so exactly communicated to the internal Parts, as to give them the same precise Velocity of Rotation as the external: Whence the Nucleus being left behind by the exterior Earth, seems to move slowly in a contrary Direction; or from East to West, with regard to the external Earth, considered as at Rest in respect of the other.

And to remove the Prejudice that may arise against this Hypothesis, on account of it's Novelty and strangeness, and to answer the Objections that may be made to it; the Doctor argues and defends the whole with great Sagacity and Probability.

Point

Point by the Compass, and the East and West by the Sun, and subtract the lesser from the greater, half the Remainder is the Declination sought; and so far the *Flower-de-Luce* is to be removed from the North End of the Needle.

THIS Method hath two Disadvantages; 1. The Sun seems to rise when it is thirty four Minutes under the Horizon; which will cause some Error in the Declination: and tho' near the Equator 'tis but small, yet in Places remote it will arise to two Degrees. 2. The Sun is often covered with Clouds when rising, and always almost in the *Torrid Zone*.

THEREFORE Seamen sometimes use another Method, that is not so liable to Error. They observe the Point the Sun is in by the Compass any time after it's rising, and then take the Altitude of the Sun; and in the afternoon they observe when the Sun comes to the same Altitude, and observe the Point the Sun is then in by the Compass, for the middle between these two is the true North or South point of the Compass; and the difference between that and the North or South upon the Card which is pointed out by the Needle, is the Variation of the Compass, and shews how much the North and South given by the Compass, deviates from the true North and South points of the Horizon.

EXAMPLE.

SUPPOSE in the forenoon Observation, when I take the Sun's Altitude, I find the Sun, by my Azimuth Compass, to bear South-East; then waiting till the Sun in the afternoon declines to the same Altitude, as in the forenoon Observation, I find by the Azimuth Compass that he bears West-South-West, the middle Point between South-East
East

East and West-South-West, if reckoned to the southward, is South by West, or if to the northward, it is North by East, which proves that the South by West point of the Compass, is the true South, and the North by East Point, is the true North, and as the *Flower-de-Luce*, or North point of the Compass, lies one point to the westward of the North by East point of the Compass, which points to the true North, it proves that the Variation is one Point westerly, or that the *Flower-de-Luce* lies one point to the westward of the true North, &c.

THEY sometimes use a fourth Method. They that are skilled in spherical Trigonometry, or can use an universal Planisphere, by taking only one Observation of the Sun's Altitude, by which, with the Latitude of the Place, and the Sun's Declination, those that understand spherical Trigonometry may find the Sun's true Azimuth, or point of the Compass that he bears upon, in the Heavens, which compared with the point that the Sun bears upon by the Compass, their difference is the Variation; as for Instance, if the Sun's Azimuth found by Calculation be 45 Degrees, or 4 Points, from the North westerly, which to speak in the Terms of Navigation is North-West, but if by the Compass, the Sun bears at the same time North-West by North, that Point difference is the Variation of the Compass, and shews that the North Point of the Compass declines one Point to the westward, or that the Variation is one Point westerly; and then will every Point of the Compass be removed, one Point towards the left Hand, as the West Point of the Compass will stand West by South, the South Point will direct to the true South by East, &c.

THIS being a thing so useful at Sea, and a great many having Tables of Logarithms, Sines, and

and Tangents that do not thoroughly understand spherical Trigonometry ; it may not be amiss, for the sake of such, to insert the following Operation to find the Sun's Azimuth, for which the most convenient *Data*, as being both the most easily found, and the least trouble in the Operation, is,

THE Sun's Altitude, his Declination, and the Hour of the Day given to find his Azimuth.

Note. The Sun's Altitude is found by a Quadrant, his Declination by the Tables for that purpose, in most Books of Navigation, and the Hour of the Day by a good Watch ; and then,

AS Sine Complement of Sun's Altitude, to Sine of the Hour from Noon, So Sine Complement of Declination to Sine of the Sun's Azimuth, from the South or North.

EXAMPLE.

LET the Sun's Altitude be 47 48 (it's Complement is 42 12) the Hour from 12, is 2 Hours 9 Minutes which is either 9 Minutes after 2, or 9 before 10, which, at 15 Degrees to an Hour, is 32 15, the Declination 20 12 North, it's Complement 69 48 then

	<i>Co. Ar.</i>
As Sine Comp. of Altitude —	42.12.0.17281
To Sine of the Hour from Noon	32.15.9.72723
So Sine Comp. Declination —	69.48.9.97243
To Sine of the Azimuth —	48.12.9.87247

WHICH 48 12 is the Sun's Azimuth from the South, or taken from 180 Degrees, leaves 131.48 the Azimuth from the North.

ANOTHER way to find the Azimuth, is by having the Latitude of the Place, the Declination

nation of the Sun, and the Sun's Altitude given, and then the Method of finding it is,

A D D the Complement of Altitude (or Zenith Distance), the Complement of Latitude of the Place, and the Complement of the Sun's Declination together, and from their half Sum substract the Complement of Declination.

T H E N to the Complement Arithmetical of the Sines of the Complement of Latitude, and of the Complement of Altitude, add the Logarithm Sines of the half Sum, and remainder half, the Total of these four Logarithms, is the Sine Complement of half the Azimuth.

Note. If the Sun's Declination be South, and the Latitude North, or the Declination North and Latitude South, you must, instead of the Complement of Declination, use the Declination added to 90, for what is there meant by the Complement of the Sun's Declination, is always it's Distance from the elevated Pole.

E X A M P L E.

	D. M.	
Sun's Altitude —	8 10	} To find the Azimuth.
Declination South -	20 13	
Latitude North —	51 32	

	D. M.
Complement of Altitude — — —	81 50
Complement of Latitude — — —	38 28
Declination added to 90 Degrees —	110 13
Sum —————	230 31
Half Sum —————	115 15
Complement of Declination —————	110 13
Remainder —————	5 2

OPERATION.

Comp. Altitude	—	81	50	Co. Ar.	0.00442
Comp. Latitude	—	38	28	—	0.20616
Sine of the $\frac{1}{2}$ Sum	-	115	15	—	9.95638
Sine of Remainder	—	5	2	—	8.94317
Sum					19.11013
Half Sum					9.55506

THAT half Sum is the Sine Complement of 68 57, which doubled is 137 54, the Azimuth from the North required.





C H A P. XXXIX.

Of the Line of a Ship's way.

THIS is the most difficult Part in all Geography, of which Authors have written so obscurely, and a great many so falsely, that the Readers can only have from them an obscure Idea without understanding them. We shall endeavour to give an Explication as clear and distinct as possible : and the Reader must give close Attention to it, and to make this Explanation the more compleat, and render those Directions intelligible and applicable, which have been left so obscure and impracticable, we shall, in this Edition, exhibit those Methods, by which not only a general Idea of Navigation may be formed, but by which also all the useful practical parts thereof are actually performed, and that with respect to Course, Distance, Latitude, Longitude, and all the *Data* and *Quesita* that can occur in the Practice of Navigation, in order to which (omitting plain Sailing, which is but the A B C of Navigation, and falsely supposes the Surface of the terraqueous Globe to be a regular Plain) we shall act from another Foundation, and deduce all our subsequent Rules and Tables from that Supposition, or rather reality of the Earth's being a Globe ; and not only adapt our Tables to that Principle, but give the Reasons and Constructions of them, in

in order to the better understanding of which the following Propositions are previously necessary.

PROPOSITION I.

If two Places are situated in one Meridian, or lie North or South from it, all the Places between them will be situated the same way from them.

THE Proposition is manifest, if rightly conceived. By the Places between two Points we understand all the Places in that Arc of a great Circle, which passes thro' the two Places. Call the first Place from which the other lies, the first Place; and the Place of the other the second Place; and the first Place is to be conceived, as if it lay in the middle of the other Places about it, and under the brass Meridian in the Globe, and an infinite Number of vertical Circles drawn from it to the Horizon, thro' the other Places, and so the Angle made, with the Meridian of the first, is the Angle wanted; for that Angle denotes the Situation of the second Place from the first. If then we conceive all the Points between two Places of the same Meridian, 'tis plain all their Meridians will be the same with the vertical drawn thro' all their Places; and therefore all the Places between them lie the same way from the first, either North or South.

PROPOSITION II.

If two Places be taken in the Equator, of which the Situation of the one to the other is wanted, the second will lie from the first East or West; and the second will lie the same way from all the Points between them.

FOR the understanding whereof, take a Point on the Equator, and let the wooden Horizon represent it's Horizon, or the Poles of the Globe be brought to the Horizon; then take another Place on the Equator, whose Situation from the first is wanted, 'tis plain it will lie either East or West; for the Equator is then a vertical Circle, which cuts the Meridian at right Angles. The same is true as to all the intermediate Points, which if brought to the brass Meridian, the wooden Horizon will be their Horizon, and the Equator a Prime vertical to them which cuts the Meridian at right Angles; and therefore the second will lie the same way from all the intermediate Points either eastward or westward.

PROPOSITION III.

If the second Place be not situated in one and the same Meridian with the first, or both not in the Equator; the second Place will not be situated from the intermediate Point, on the same Point of the Compass but in different Points in different Places.

ON this depends the Knowledge of the Line which a Ship describes; and therefore Readers should understand it well.

TAKE two such Places on the Globe, as *Amsterdam* from which, and *Pernambucca* in *Brasil* to which, the Voyage is to be made, bring *Amsterdam* to the Meridian, and elevate the Globe for it's Latitude, and fix the Quadrant of Altitude at the Zenith; and turning it about to *Pernambucca* it will show, on the Horizon, the Point on which it lies from *Amsterdam*; and the Arc between them contains the intermediate Points. 'Tis to be shown that *Pernambucca* does not lie the same way from each of these Points.

AND

AND here 'tis to be remembred, that the Angle made by the Meridian of the first Place, and the Vertical of the other passing through, gives the Point that the second lies on, which is measured on the Horizon.

TO solve the Proposition ; take any two Points between two Places, 'tis better to take such two as have Circles of Longitude drawn thro' them on the Globe, and because the Quadrant passes thro' all these Places and *Pernambucca*, it will denote the Vertical in which *Pernambucca* lies from them. And thus the Angles, which that Vertical makes with the Meridian of each Place is the Angle of Position, and shows the Points that *Pernambucca* lies in from each intermediate Point ; but these Angles are not all of the same Degrees, as appears to the Sight. Or more plainly, if you measure them with the Compass, or by the help of a Curve that can be adapted to the Globe ; or if the Places be brought to the Zenith, and the Pole elevated for their Latitudes, and the Quadrant applied to each, you will have the Angle in Degrees on the Horizon.

COROLLARY.

THE rectilineal Maps, or Sea-Charts, are then very faulty, for there one Place seems to be on the same Point from another with all the intermediate Places, because their Meridians are parallel, tho' they meet at the Pole ; but Seamen do not regard that, if they can first see the Point that the Places they sail to lies in, from the Places they come from.

PROPOSITION IV.

If a Ship be to sail from one Place to another, that does not lie in the same Meridian, or both in the Equator, so as to keep the vertical Circle between the two Places, the Ship will then every Minute change the Point she sailed on.

THIS is plain from the preceding Proposition: for supposing the Voyage from *Amsterdam* to *Pernambucca* is to be the shortest that can be drawn on the Globe; then because the Ship is always in the Voyage directed to *Pernambucca*, and as before there are still different Points in the different Meridians; 'tis plain the Ship must steer her Course on different Points, to come to *Pernambucca*: but it will be otherwise if the two Places were both in one Meridian, or on the Equator.

PROPOSITION V.

A Ship cannot always sail on different Points, but must for some time at least sail on the same Point. Therefore such Way, or Line, is to be sailed in, that the two nearest Points may be on the same Point, tho' that be not the shortest Course.

FOR all Motion is performed in some Time; nor can a Ship change it's Point every Moment, but must for some Time sail one way; nor could Seamen know the Points to steer on, if they were to change them so often. Therefore that must be the most commodious failing, in which the two nearest Points are directed the same way; so as the Ship may be directed still to the Point, and at last come to the designed Port. This then being supposed, we are to enquire what Way is best for
2 a Ship

a Ship to move in: and if the two Places are in one Meridian it will be a Part of the Meridian; if in the Equator, a Part of the Equator; if in a parallel Circle, it will be a Part of it; but if in any other Circle, it will be in another Line, and not in the Circle, as we shall show.

PROPOSITION VI.

If a Ship sail always due North or South, that is, if the Places, to which and from which, be in the same Meridian, the Ship's Way will be a Portion of the Meridian.

THIS is proved from the first Proposition of this Chapter; for the Place sailed to is situated the same way from all the intermediate Points, as was there said; but by the preceding Proposition, such a Way is to be chosen, as is most commodious, whose two nearest Points are situated the same way; and seeing an Arc of the Meridian is such a Way, this will be the Way the Ship moves in, while it goes still North or South.

PROPOSITION VII.

If a Ship sail East or West on the Equator, the Ship's Way will be a Portion of the Equator.

WE showed, in the second Proposition, that if two Places on the Equator, to which, and from which, a Ship moves, be chosen, the first Point will lie the same Way from all the intermediate Points. And because the Ship is continually directed that way, an Arc of the Equator will be the Ship's Way; and because in the fifth Proposition we supposed, that such a Way is to be chosen for the Ship's Way as is most commodious, whose

whose two adjacent Points lie the same way, a Portion of the Equator will be such a Way, and therefore to be chosen for the Ship's Way.

PROPOSITION VIII.

If a Ship, not in the Equator, move East or West, it will describe not a Part of a great Circle, but a Part of the Parallel in which it is.

BECAUSE the Ship going from one Meridian to another is supposed to be directed to the same Point, it will not move in a vertical Circle, but go to another Point in the same Parallel in another Meridian; for the Points of that Parallel are such, that if Tangents be drawn to them, they will run East and West, with respect to the same Points; and because the Ship is supposed to be still directed that way, it will always touch the Parallel in some Point; or because each two nearest Points in that Parallel, are such, that one is situated to the same East or West Point: nor is there any other Line on the Globe whose Points are such: and therefore the Ship's Way is the Parallel in which it is.

PROPOSITION IX.

If a Ship sail in the same Parallel, the Ship's Way will be a Part of the Parallel, tho' that be not the shortest Way.

FOR that Line is chosen for the Ship's Way in which the Ship can come to the designed Port; being directed still to the same Point; or whose two nearest Points lie the same Way: but the Points in a Parallel Circle are such; therefore a Part of it will be the Ship's Way.

COROL-

COROLLARY.

THERE is therefore a three-fold Situation of Places, from one of which, when we sail to the other, the Ship's Way is the Periphery of a Circle; 1. If both Places are in one Meridian. 2. If both be in the Equator; or, 3. both in the small Parallel. In the two former the Ship's Way is the same with the shortest Distance between them; but in the third Situation the Ship's Way is not the shortest Way; for that is the Arc of a great Circle between the two Points. In any other Situation of Places the Ship's Way cannot be Part of a Circle; as we shall show in the following Proposition.

PROPOSITION X.

If a Ship sail, in any Part of the Ocean, to a Point that is not a Cardinal one, and keep still to the same Point, the Ship's Way is not a Part of a Circle, or any Curve returning to itself, but a curve Line, like a spiral, turning infinitely round the Earth, and inclining continually towards the Pole but never centering in it.

LET us suppose a Ship to set sail from any Place; after 'tis come to a Point in the next Meridian, 'tis directed to that Point of the next Meridian which is situated on the same Point from the other Place left; and so in going into the other Meridians; but all these Points of those Meridians do not make a Circle, but a Curve like a Spiral. This will be better understood by seeing it on the Globe than by many Words

DEFI-

D E F I N I T I O N.

LOXODROMY is a Ship's Way, failing still to any one Point that is not one of the Cardinals.

THIS is the meaning of the Word, but the Definition of the Thing itself, according to it's Nature and Properties, is not easy to be understood; it being neither a spiral Line, as some think, nor depending on any Property of the Loadstone, as others imagine, because the Ship follows the Direction of the Needle; nor composed of the small Parts of many Circles, as *Nonnius* says, because the Parallels are made the same way by the Motion of the Ship, as the *Loxodromics*; nor is *Snellius's* Explication of it plain, who says, That the *Loxodromic* is a Line on the Superficies of the terrestrial Globe, which Surface, a right Line touching every where, makes equal Angles with all the Meridians drawn thro' these Points of Contact; for *Snellius* doth not explain how such a Tangent is to be conceived or drawn; and, properly speaking, a *Loxodromic* hath not right Lines touching it, being a solid Line; whereas Tangents are only drawn to curve plain Lines; and infinite Tangents may be drawn to each Point in solid Lines: and besides, this Definition agrees to other Draughts of Lines when such a Tangent, to any Point of a meridian and curve Line drawn from the next Meridian, may be conceived.

OUR Definition is proposed thus: *A Loxodromic Line is a curve Line surrounding the Earth by several Windings, of which any Point lies the same way from all the rest in it; or in which if two Points be taken, the one lies from the other, and all the intermediate Points, the same Way; or from each Point of which, if circular Lines be drawn to all the rest of*
the

the Points, these Arches will make the same Angles with the Meridians that pass thro' each Point. This Definition is essential, and is the true Description of the Rumb-Lines upon the Globe.

PROPOSITION XI.

If a Ship sail not on a Meridian, nor in the Eqator, nor in a parallel Circle, and be directed still in that Point in which the designed Port lies, from the Port left, the Ship will never come to the designed Port, but be removed more and more from it.

THIS famous Property in sailing was at first a Wonder to Sailors, when first observed in the last Age, or the Time of *Peter Nonnius* a Mathematician of *Portugal*; for a certain skillful Pilot, who sailing some time still eastward to a Port that lay due East from him, found that thereby he never came to it, desired that *Nonnius* would give him the Reason of so strange a thing, which gave the first rise to this Enquiry. And *Nonnius* a little after published two Books about it; and afterward several Mathematicians were at work about this curve Line; at last Sailors found there was a necessity of having regard to it, and Tables were made for it, of which afterwards.

PROPOSITION XII.

1. *When a Ship is to sail in the same Meridian, or North and South, she must be directed if possible still one Way; that is, the Meridian must be the Ship's Way.*

2. WHEN a Ship is to sail from one Place in the Equator to another in it, that is either East
or

or West, the Ship must be directed that Way, or the Equator must be the Ship's Way.

3. WHEN a Ship is to sail from one Place in a parallel Circle, to another in it, she must not be directed to the Point in which the one Place lies from the other, else she would never come to it, but wind about the Earth, as it were, in a spiral Line, towards the Poles; but the Pilot is to steer due East and West; for thus she describes a Parallel to the Equator, and so will come to her Port.

4. WHEN a Ship is to sail from one Place to another, which are neither in one Meridian, nor in the Equator, nor in a parallel Circle, the Ship is not to be directed to that Point in which the first Place lies from the second, for thus the Ship would describe a *Loxodromic* Curve, which will not pass thro' the other Place; but the Direction must be in that Line, which when the Ship goes, she will describe a *Loxodromic*, that will pass thro' the other Place, or into that Line which makes an Angle, with the Meridian, equal to the Inclination of the *Loxodromic* which passes thro' these two Places. These all follow from the preceding Proposition.

PROPOSITION XIII.

An infinite Number of Loxodromics may be conceived to come from any place of the Earth, and also infinite Verticals; but there are only counted twenty eight round about a place, viz. seven in the Quadrant between the Meridian and Parallel of the place; and so they divide the Angle into eight equal Parts, and each two nearest are distant equally; but the Parallel is called the eighth Loxodromic.

THEY are called by the same Names that the Winds or Points are. They that are seen on the
Globes

Globes come from the Center of the Sea-Compass on it, and also from other Points of the Meridian and to turn round the Earth.

AND for Practice at Sea; the intermediate *Loxodromics* are denominated by their Distance from the next *Loxodromic*. For Example; One third, or one fourth, more northerly or easterly, &c.

PROPOSITION XIV.

The Loxodromic between any two Places is (as to Sense) equal to the Hypotenuse of a plain right-angled Triangle, one Leg being equal to the Difference of the Latitude of those two Places, the other equal to the Difference of their Longitude taken on a Parallel, which is in the middle between the Parallels of the two places.

SUCH Triangles are called *Loxodromics*; but for accurate Calculation, Places must be taken very near one another, even within a Minute.

COROLLARY.

WE may hence calculate the *Loxodromic Line* from one place to another; and that with the help of the following Proposition.

PROPOSITION XV.

The Parts of one Loxodromic intercepted between Parallels equi-distant are equal.

THEREFORE a great many small *Loxodromic Triangles* may be conceived in each *Loxodromic*; of which if the *Loxodromic* of one be calculated, the Quantity of the *Loxodromic* from one Place

Place to another, whose Latitude is known, is known also.

PROPOSITION XVI.

Having the Difference of the Latitude and Longitude of two Places, to find the Loxodromic in which a Ship must sail from one Place to the other; or having on the Globe two Places, to find which way a Ship must steer in going from one to the other.

THIS is the chief Problem in Navigation, to which the rest are subservient. If there be no Difference of Latitude, the Ship's Way will not be a *Loxodromic*, but a Parallel of these Places; tho' 'tis commonly called the eighth *Loxodromic*, because 'tis formed the same way as the rest, by the Motion of the Ship, which is directed East or West. If therefore their Latitude be the same, they say the eighth *Loxodromic* should be taken, and the Ship steered still due East or West, tho' not strait to the designed Port, yet by that false Direction the Ship will come to it.

IF there be no Difference of Longitude, there will be no *Loxodromic*, but a Part of the Meridian of both Places; and the Ship is to be directed North or South.

BUT if the Places differ both in Latitude and Longitude, and you would work by the Globe, let the given Latitudes be marked on the brass Meridian, and if the Parallel of one Latitude have on it the Center of a Sea-Compass, from which *Loxodromics* are drawn, bring that Center to the Meridian, under the marked Latitude; then turn the Globe 'till as many Degrees on the Equator pass thro' the Meridian, as are in the Difference of Longitude; then observe in what *Loxodromic* the Point is which is under the other marked Point
of

of the Meridian, and that will be the one sought, which will shew to what Point the Ship is to be directed, to come to the designed Place. If there be not a Point of a *Loxodromic* under the Mark, the middle must be taken between the two next *Loxodromics*.

BUT if there be not the Center of a Compass in any of the two Parallels, chuse a *Loxodromic* that seems near that which is wanted, which bring to one Point mark'd on the Meridian, and turn the Globe, as before, 'till the Difference of Longitude pass thro' the Meridian; and if a Point of the assumed *Loxodromic* be under the other Point marked in the Meridian, you have it at once; if not, assume another Meridian, and try, as before, 'till you find a Point in the *Loxodromic* under the Mark, or near it; and call it by the nearest *Loxodromic*, or by how much 'tis beyond, or comes short of it.

IN the Sea-Charts it is as the Point the one lies in from another, tho' in those of equal Degrees of Latitude 'tis false; but of unequal 'tis accurate enough.

SAILORS have also another Method, easy enough, by the Solution of right-angled plain Triangles; but for this they use a Table of meridional Parts; of which we treated in *Chap. xxxii*, and now proceed to give the Original and Construction thereof, with it's application to the finding the *Line of a Ship's way*, according to our promise in the Title of this Chapter.

IN order the better to understand the Nature of the Table of meridional Parts, we are to consider, that this Earth, upon which we live, as composed of Land and Sea, is a Globe, or of a globular Form, and moves upon it's own Axis, which is terminated by two Poles, or opposite Points of the Surface of the Earth, between which,

and equally distant from each, is the Equator which passes round the Earth, and divides it equally into the northern and southern Hemispheres; and any other Circles drawn round the Globe, or imagined to be drawn round the Earth it self, parallel and equidistant from the Equator, either on the North or South of it, are called *Parallels of Latitude*, North or South, according to their Situation from the Equinoctial; also any Lines drawn along the Surface of the Globe, at the nearest distance from Pole to Pole, (or imagined to be drawn so upon the Surface of the Earth) are called *Meridians*, which therefore at whatsoever Distance they may be from one another in the Equinoctial, yet as they all meet, and concur in the Poles, they incline nearer to each other as they approach it; and as every two Meridians contain the same number of Degrees of Longitude, as they come nearer the Poles, which were contained between them in the Equator, when further asunder, it will follow that a lesser Space, or fewer Miles, make a Degree of Longitude nearer the Poles, than are contained in a Degree of Longitude, in the Equator; and as a Degree of Longitude in the Equator, is always equal to a Degree of Latitude, upon any part of the Globe; it will necessarily follow, a Degree of Longitude bears continually a less proportion to a Degree of Latitude, as they approach nearer either Pole.

BUT as former Authors have not found any way to transfer those curving inclining Meridians from the Globe to a Plain, it being impossible for a true plain to co-incide with the Surface of a Globe, or (Mathematically speaking) so much as to touch it any where, but in a Point, as a right Line can touch a Circle, they concluded Globular Sailing impracticable, and for many Years contented themselves with Plain Sailing, which, with-

out any regard to the Convexity of the Earth, supposeth it to be a plain Superficies only.

BUT our ingenious Countryman Mr *Edward Wright*, very sensible of the Errors which must unavoidably be the consequence of trusting our Navigation upon a Supposition so evidently false, substituted another Projection instead of the plain Chart, which is now (though wrongfully) known by the name of *Mercator's* Chart. In this, although the Degrees of Latitude are not every where equal, as they are upon the Globe, and consequently the same extent of the Compasses will not contain just the same Number of Miles in every part of the Chart; yet it is so contrived, that the Degrees of Longitude bear the same proportion to the Degrees of Latitude in any Parallel, that they do in the same Parallel upon the Globe, which is an Excellency, that the plain Chart is entirely a Stranger to.

IN this Chart the Degrees of Longitude are every where equal, and therefore to keep the Meridians parallel, and retain the same proportion between the Degrees of Longitude, and the Degrees of Latitude that there is upon the Globe, the Degrees of Latitude upon the Meridian are protracted, or lengthened; so that whereas upon the Globe, the Degrees of Latitude are every where equal, viz. 60 Miles to a Degree, and in Latitude 60 Degrees, one Degree of Longitude, is but half as much as a Degree of Latitude, viz. 30 Miles; so in *Mercator's* Projection, a Degree of Longitude is the same in Latitude 60, as it is under the Equinoctial, and a Degree of Latitude is twice as long; and in like manner, the same proportion is held between the Degrees of Latitude and Longitude, upon *Mercator's* Chart every where as is upon the Globe.

BUT although the Degrees of Longitude and Latitude, did by this means retain their true pro-

portion between themselves, yet as the Degrees of Longitude are every where the same, it will follow, that the Meridians, and consequently the Distances, are every where (except under the Equinoctial) distorted, and the more so as they come nearer the Pole, insomuch that the same extent of the Compass, which contains 60 Miles under the Equinoctial, contains but 20 Miles, or less, between Latitude 70 and 71, and nearer the Poles.

BUT as it was pity such an excellent Invention should be lost, for want of a way to measure Distances upon it, we have likewise subjoined the Method of making a Scale, whereby at one Extent to measure a Distance upon *Mercator's* Chart: The Scale is formed from the same mathematical Principles with the Chart itself; we shall first give the Construction of one, and then of the other.

WE have observed above, that by reason of the Difficulty of truly drawing upon a plain, any considerably part of the Surface of the Globe, with inclining Meridians, and all the other properties of the Globes, they endeavoured to find out a right lined Projection, which might be equally true, and yet easier in Practice, in order to which it is premised, as a Foundation,

1. THAT the Peripheries, or Circumferences, of all Circles, are in a direct proportion to their Diameters; and consequently to their Semidiameters or Radiuses. And,

2. As the Periphery of one Circle, to the Periphery of another, of a different Magnitude, So a Half or a Quarter, or any other part of the first Circle's Periphery, to the like part of the other Circle's Periphery.

3. The Semidiameter or Radius of any Parallel of Latitude, is the Sine Complement of that Latitude; these considered it will be then,

1. A S Radius: To Sine Complement of any given Latitude, So 60, the Miles in a Degree of Longitude in the Equator, to the number of Miles contained in a Degree of Longitude, in the Latitude proposed.

2. BUT it is also demonstrable, that As Sine Complement of any Arch to Radius, So is Radius to the Secant of the same Arch.

IN the Scheme let C be the Center of the Earth, and A B D be a Quarter of a Meridian, let A be the Pole, and C D the Semidiameter, or Radius of the Equinoctial, draw the Tangent D E, and the Secant C B E, draw also the perpendicular B G (the right Sine of the Arch D B) and F B equal to C G, the Sine Complement of the same Arch, then is B D the Latitude or Distance of B from the Equinoctial: A B the Complement of Latitude: B G is the Sine of the Latitude, and C G equal to F B the Sine Complement of Latitude. C B equal to C D is Radius, D E the Tangent, and C E the Secant of the Latitude.

H E N C E, for the first, it will be, As C D, (*Plate XI. Fig. B.*) the Radius or Semidiameter of the Equinoctial, To C G equal to F B, So one Degree, or any other part of the Equinoctial to one Degree, or the like part of the Parallel passing through B, that is as Radius to the Sine Complement of Latitude, So 60, the Miles in a Degree of the Equinoctial, to the Miles in one Degree of Longitude, in the Parallel of B.

Secondly, As C G (equal to F B) Sine Complement of Latitude, to C B (equal to C D) Radius, So C D Radius to C E the Secant of Latitude *Euclid, Lib. vi. Prop. iv.*

T H I S being granted, it may thus be applied to a Demonstration of the truth of the Construction of *Mercator's*, or, more justly, Mr *Wright's* Chart.

IN this Projection the Meridians are proposed parallel to each other, and consequently the Diameter of any or every Parallel, is likewise supposed equal to that of the Equator, and hence the Radius of any Parallel is equal to the Radius of the Equator; and therefore, in the last mentioned Scheme, FB or CG will be every where equal to CD, but when CG is become equal to CD, it is evident CB will become equal to CE, and consequently the Radius of the Meridian, at any Parallel, will be equal to the Secant of the Latitude of that Parallel, also as a Degree, or any small Arch upon the Equator, is equal to a Degree, or the like Arch upon the Meridian, upon the Globe, it will be as the Secant of any Parallel is to Radius, so is the length of a Degree, or any small Arch upon the Meridian, to the Length of a Degree, or the like Arch upon that Parallel, and therefore a Degree on any Parallel, will be increased in the same Proportion, as the Secant of Latitude is greater than Radius; as for Instance, the Secant of 60 is just twice Radius, therefore a Degree of Longitude which should be but half as much as a Degree of Longitude in the Equinoctial, is there, and all over the Projection, equal to a Degree in the Equinoctial, and therefore in Latitude 60 just twice as large as it should be, and the Degrees of Latitude which are every where equal upon the Globe, are double in Latitude 60, to what they are in the Equinoctial, by which means the proportion in northing and southing, is the same to that of the easting and westing upon this Projection, as it is upon the Globe, and the Length of a Degree, or any small Arch upon the enlarged Meridian, must every where be to a Degree, or like Arch of the Meridian on the Globe, as the Secant of the Latitude is to Radius.

HENCE

HENCE supposing any small Arch of the Meridian to be Radius, the following Corollaries may be deduced.

1. THAT the Length of a Degree, or any small Arch upon the enlarged Meridian, is every where equal to the Secant of the Arch contained between it and the Equator.

2. THE distance of any Point in the enlarged Meridian from the Equator, is equal to the Sum of all the Secants contained between it and the Equator.

3. THE Distance between any two Parallels, on the enlarged Meridian (being both on the same Side of the Equator) is equal to the Difference of the Sums of all the Secants of every Minute, contained between each Parallel and the Equator.

4. THE Distance between any two Parallels upon the enlarged Meridian (being on contrary sides of the Equator) is equal to the Sum of the Sums of all the Secants contained between each Parallel and the Equator.

UPON the Principle of this second Corollary it is that the Table of meridional Parts is formed; *viz. That the Distance of any Point, upon the enlarged Meridian, from the Equator, is equal to the Sum of all the Secants contained between it and the Equator.* It is plain that if to 00000 (which if the expression be proper, may be said to be the meridional Parts of 00 deg. 00 min.) we add the natural Secant of 00 deg. 0 min. *viz.* 10000, the Sum will be 10000 the meridional Parts for 0 deg. 1 min. to which if we add the natural Secant of 0 deg. 2 min. which is again 10000 (because the Secants of such small Arches, where they fall upon the tangent Line, at so near a right Angle, increase insensibly) the Sum is 20000, the meridional Parts for 2 deg. 00 min. &c. But this will appear more conspicuous towards the latter part of the Table,

where the natural Secants, and consequently the meridional Parts, increase much faster; and to make it more intelligible, we shall have recourse to that excellent Book, entituled *Correction of Errors in Navigation*, written by the ingenious Mr *Edward Wright*, the first Inventor of the Projection we are now treating of, and of the Table of meridional Parts, by which it is projected, and the Operations therein performed. According to his Table of Latitudes (being of the same Construction and Use, with those we now call Tables of meridional Parts) and Mr *Sherwin's* or any correct Table of natural Secants, we shall find, by the continual Addition of the Secant of the succeeding Minute, to the meridional Parts of the Minute proposed, the Sum is the meridional Parts of the said succeeding Minute, &c. as above, and as in the following Instances in finding the meridional Parts to higher Latitudes.

E X A M P L E.

	D. M.	
The Meridional Parts of —	79 20	is 81540915
Secant of the next Minute viz.	79 21	54109
Meridional Parts of — —	79 21	81595024
Secant of —————	79 22	54193
Meridional Parts of —————	79 22	81649217
Add the Secant of —————	79 23	54277
Meridional Parts of —————	79 23	81703494
Add Secant of —————	79 24	54362
Meridional Parts of —————	79 24	81757856
Add Secant of —————	79 25	54446
Meridional Parts of —————	79 25	81812302

IN this manner (not to proceed any further by way of Example) are all the meridional Parts, from 00 deg. 00 min. to 89 deg. 59 min. produced,
it

it being impossible to produce the Meridional Parts, of 90 *deg.* 00 *min.* because it's Secant is infinite, and in the Projection it is impossible to represent the Pole, because upon the Globe, the Meridians incline, and at last concur in the Pole; but in the Projection, the Meridians, being parallel to each other, could not, in the greatest imaginable Space, concur in a Point, and yet without such a Concurrence of the Meridian, it is impossible to form or imagine a Pole or Poles to the Globe; however that Difficulty is obviated, when we consider that these Tables of meridional Parts approach much nearer the Poles, than any Navigation is practicable, and therefore do fully answer the End for which they were intended.

BUT tho' Mr *Wright* in his Table of Latitudes (and we after him in this Example) have inserted the meridional Parts to so many places, yet it is thought sufficiently exact for Practice to cast away the last four Figures towards the right Hand; and use the rest; only if the first towards the left Hand of those cut off, be above a 5 add 1 to the right Hand Figure of those reserved for use and thus are the meridional Parts produced, that are in *Seller's Navigation*, *Wilson's Navigation*, and other Practical Books; as for Instance, Mr *Wright* makes the meridional Parts for 19 *deg.* 12 *min.* to be 11741560, but these Authors cutting off four Figures towards the right Hand, make it only 1174. But Mr *Wright* making the Meridian Parts of 79 *deg.* 24 *min.* to be 81757856, if four Figures towards the right Hand were cut off, without any regard to the first towards the left Hand of those so cut off, the Figures reserved for use would be 8175, but the next Figure being above 5, *viz.* 7, these Authors add 1, to the last Figure, which is 5, and the meridional Parts for 79 *deg.* 24 *min.* is 8176; I shall only add

add, that the greater number of places that the meridional Parts are calculated to, they are more exact, but they are sufficiently so for Practice, when those four places towards the right Hand are cut off, the Error contracted thereby (if any at all) not being perceptible.

BUT notwithstanding what has been said, as to the abridging the number of Figures in the meridional Parts, it is adviseable, in the composing them by the addition of Secants, that the Secants made use of for that purpose, do not consist of a number of places, less than five at least.

BUT if a Table of meridional Parts, be made but to every other Minute as 0, 2, 4, 6, &c. Minutes above every Degree, add the Secants of the two succeeding Minutes to the Meridional Parts, found for the Minute proposed, the Sum is the meridional Parts of the next Minute but one.

EXAMPLE.

	D. M.	
Meridional Parts for —	63 26	49630758
Secant of —————	63 27	22372
Secant of —————	63 28	22385
Meridional Parts for —————	63 28	<u>49675515</u>

THIS is so easy, that it needs no more *Examples*.

AND to find the meridional Parts of the intermediate Minute 63 27. The meridional parts, for 63 26 (using only the first four Figures) is 4963, and for 63 28, the meridional Parts is 4967, the Difference is 4, the half of which, 2, added to the least, viz. 4963, the meridional Parts of 63 26, the Sum 4965 is the meridional parts of 63 27 required, and the Difference being so small, may be readily done by the mind without the help of Pen and Ink.

FROM this Construction the following Table of meridional Parts is calculated.

A TABLE

A
T A B L E
O F
MERIDIONAL PARTS,
O R
M I L E S
To every other Minute of the
MERIDIAN.

A Table of Meridional Parts.

<i>Min.</i>	<i>D.</i>	<i>Deg.</i>	<i>Deg.</i>	<i>Deg.</i>	<i>Deg.</i>	<i>Deg.</i>	<i>Deg.</i>	<i>Deg.</i>
	0	1	2	3	4	5	6	7
0	0	60	120	180	240	300	361	421
2	2	62	122	182	242	302	363	423
4	4	64	124	184	244	304	365	425
6	6	66	126	186	246	306	367	427
8	8	68	128	188	248	308	369	429
10	10	70	130	190	250	310	371	431
12	12	72	132	192	252	312	373	433
14	14	74	134	194	254	314	375	435
16	16	76	136	196	256	316	377	437
18	18	78	138	198	258	318	379	439
20	20	80	140	200	260	320	381	441
22	22	82	142	202	262	322	383	443
24	24	84	144	204	264	324	385	445
26	26	86	146	206	266	326	387	447
28	28	88	148	208	268	328	389	449
30	30	90	150	210	270	330	391	451
32	32	92	152	212	272	332	393	453
34	34	94	154	214	274	334	395	455
36	36	96	156	216	276	336	397	457
38	38	98	158	218	278	338	399	459
40	40	100	160	220	280	340	401	461
42	42	102	162	222	282	342	403	463
44	44	104	164	224	284	344	405	465
46	46	106	166	226	286	346	407	467
48	48	108	168	228	288	348	409	469
50	50	110	170	230	290	350	411	471
52	52	112	172	232	292	352	413	473
54	54	114	174	234	294	354	415	475
56	56	116	176	236	296	356	417	477
58	58	118	178	238	298	358	419	479

A Table of Meridional Parts.

<i>Min.</i>	<i>Deg.</i> 8	<i>Deg.</i> 9	<i>Deg.</i> 10	<i>Deg.</i> 11	<i>Deg.</i> 12	<i>Deg.</i> 13	<i>Deg.</i> 14	<i>Deg.</i> 15
0	481	542	603	664	725	787	848	910
2	483	544	605	666	727	789	850	912
4	485	546	607	668	729	791	852	914
6	488	548	609	670	731	793	855	917
8	490	550	611	672	733	795	857	919
10	492	552	613	674	735	797	859	921
12	494	554	615	676	737	799	861	923
14	496	556	617	678	740	801	863	925
16	498	558	619	680	742	803	865	927
18	500	560	621	682	744	805	867	929
20	502	562	623	684	746	807	869	931
22	504	564	625	686	748	809	871	933
24	506	566	627	688	750	811	873	935
26	508	568	629	690	752	813	875	937
28	510	570	631	692	754	815	877	939
30	512	573	633	695	756	817	879	941
32	514	575	635	697	758	820	881	944
34	516	577	638	699	760	822	883	946
36	518	579	640	701	762	824	886	948
38	520	581	642	703	764	826	888	950
40	522	583	644	705	766	828	890	952
42	524	585	646	707	768	830	892	954
44	526	587	648	709	770	832	894	956
46	528	589	650	711	772	834	896	958
48	530	591	652	713	774	836	898	960
50	532	593	654	715	776	838	900	962
52	534	595	656	717	778	840	902	964
54	536	597	658	719	781	842	904	966
56	538	599	660	721	783	844	906	968
58	540	601	662	723	785	846	908	971

A Table of Meridional Parts.

Min.	Deg. 16	Deg. 17	Deg. 18	Deg. 19	Deg. 20	Deg. 21
0	973	1035	1098	1161	1225	1289
2	975	37	1100	63	27	91
4	977	39	02	66	29	93
6	979	41	04	68	31	96
8	981	44	07	70	34	98
10	983	1046	1109	1172	1236	1300
12	985	48	11	74	38	02
14	987	50	13	76	40	04
16	989	52	15	78	42	06
18	991	54	17	80	44	08
20	993	1056	1119	1183	1246	1311
22	996	58	21	85	48	13
24	998	60	23	87	51	15
26	1000	62	25	89	53	17
28	02	64	28	91	55	19
30	1004	1067	1130	1193	1257	1321
32	06	69	32	95	59	23
34	08	71	34	97	61	26
36	10	73	36	1200	63	28
38	12	75	38	02	66	30
40	1014	1077	1140	1204	1268	1332
42	16	79	42	06	70	34
44	18	81	44	08	72	36
46	21	83	47	10	74	38
48	23	85	49	12	76	41
50	1025	1088	1151	1214	1278	1343
52	27	90	53	16	81	45
54	29	92	55	19	83	47
56	31	94	57	21	85	49
58	33	96	59	23	87	51

A Table of Meridional Parts.

<i>Min.</i>	<i>Deg.</i> 22	<i>Deg.</i> 23	<i>Deg.</i> 24	<i>Deg.</i> 25	<i>Deg.</i> 26	<i>Deg.</i> 27
0	1354	1419	1484	1550	1616	1683
2	56	21	86	52	19	86
4	58	23	88	54	21	88
6	60	25	91	57	23	90
8	62	27	93	59	25	92
10	1364	1429	1495	1561	1628	1695
12	67	31	97	63	30	97
14	69	34	99	65	32	99
16	71	36	1501	68	34	1701
18	73	38	03	70	36	1704
20	1375	1440	1506	1572	1639	1706
22	77	42	08	74	41	08
24	79	45	10	76	43	10
26	82	47	12	79	45	13
28	84	49	15	81	48	15
30	1386	1451	1517	1583	1650	1717
32	88	53	19	85	52	19
34	90	56	21	87	54	22
36	92	58	23	90	57	24
38	95	60	26	92	59	26
40	1397	1462	1528	1594	1661	1728
42	99	64	30	96	63	31
44	1401	66	32	99	65	33
46	03	69	34	1601	68	35
48	05	71	37	03	70	37
50	1408	1473	1539	1605	1672	1740
52	10	75	41	07	74	42
54	12	77	43	10	77	44
56	14	80	45	12	79	47
58	16	82	48	14	81	49

A Table of Meridional Parts.

<i>Min.</i>	<i>Deg.</i> 28	<i>Deg.</i> 29	<i>Deg.</i> 30	<i>Deg.</i> 31	<i>Deg.</i> 32	<i>Deg.</i> 33
0	1751	1819	1888	1958	2028	2099
2	53	22	91	60	31	2102
4	56	24	93	63	33	04
6	58	26	95	65	35	07
8	60	28	98	67	38	09
10	1762	1831	1900	1970	2040	2111
12	65	33	02	72	42	14
14	67	35	04	74	45	16
16	69	38	07	77	47	19
18	71	40	09	79	50	21
20	1774	1842	1911	1981	2052	2123
22	76	45	14	84	54	26
24	78	47	16	86	57	28
26	81	49	18	88	59	31
28	83	51	21	91	61	33
30	1785	1854	1923	1993	2064	2135
32	87	56	25	95	66	38
34	90	58	28	98	69	40
36	92	61	30	2000	71	43
38	94	63	32	02	73	45
40	1797	1865	1935	2005	2076	2147
42	99	68	37	07	78	50
44	1801	70	39	09	80	52
46	03	72	42	12	83	55
48	06	74	44	14	85	57
50	1808	1877	1946	2017	2088	2159
52	10	79	49	19	90	62
54	12	81	51	21	92	64
56	15	84	53	24	95	67
58	17	86	56	26	97	69

A Table of Meridional Parts.

<i>Min.</i>	<i>Deg.</i> 34	<i>Deg.</i> 35	<i>Deg.</i> 36	<i>Deg.</i> 37	<i>Deg.</i> 38	<i>Deg.</i> 39
0	2171	2244	2318	2393	2468	2545
2	74	47	20	95	71	47
4	76	49	23	98	73	50
6	79	52	25	2400	76	52
8	81	54	28	03	78	55
10	2183	2256	2330	2405	2481	2558
12	86	59	33	08	83	60
14	88	61	35	10	86	63
16	91	64	38	13	89	66
18	93	66	40	15	91	68
20	2196	2269	2343	2418	2494	2571
22	98	71	45	20	96	73
24	2200	74	48	23	99	76
26	03	76	50	25	2501	78
28	05	78	53	28	04	81
30	2208	2281	2355	2430	2506	2584
32	10	83	58	33	09	86
34	13	86	60	35	12	89
36	15	88	63	38	14	91
38	17	91	65	40	17	94
40	2220	2293	2368	2443	2519	2597
42	22	96	70	45	22	99
44	25	98	73	48	24	2602
46	27	2301	75	50	27	04
48	30	03	77	53	29	07
50	2232	2306	2380	2456	2532	2610
52	34	08	83	58	35	12
54	37	11	85	61	37	15
56	39	13	88	63	40	17
58	42	15	90	66	42	20

A Table of Meridional Parts.

<i>Min.</i>	<i>Deg.</i> 40	<i>Deg.</i> 41	<i>Deg.</i> 42	<i>Deg.</i> 43	<i>Deg.</i> 44	<i>Deg.</i> 45
0	2623	2702	2782	2863	2946	3030
2	25	04	84	66	49	33
4	28	07	87	69	51	36
6	30	10	90	71	54	38
8	33	12	92	74	57	41
10	2636	2715	2795	2877	2960	3044
12	38	17	98	80	63	47
14	41	20	2801	82	65	50
16	44	22	03	85	68	53
18	46	25	06	88	71	55
20	2649	2728	2809	2890	2974	3058
22	51	31	11	93	76	61
24	54	33	14	96	79	64
26	57	36	17	99	82	67
28	59	39	20	2902	85	70
30	2662	2741	2822	2904	2988	3073
32	65	44	25	07	90	75
34	67	47	28	10	93	78
36	70	49	30	13	96	81
38	73	52	33	15	99	84
40	2675	2755	2836	2918	3002	3087
42	78	58	39	21	05	90
44	80	60	41	24	07	93
46	83	63	44	26	10	95
48	86	66	47	29	13	98
50	2688	2768	2849	2932	3016	3101
52	91	71	52	35	19	04
54	94	74	55	37	22	07
56	96	76	58	40	24	10
58	99	79	60	43	27	13

A Table of Meridional Parts.

Min.	Deg. 46	Deg. 47	Deg. 48	Deg. 49	Deg. 50	Deg. 51
0	3116	3203	3292	3382	3475	3569
2	18	06	95	85	78	72
4	21	09	98	88	81	75
6	24	12	3301	91	84	78
8	27	15	04	94	87	82
10	3130	3217	3307	3397	3490	3585
12	33	20	10	3400	93	88
14	36	23	13	03	96	91
16	39	26	16	07	99	94
18	42	29	19	10	3503	98
20	3144	3232	3322	3413	3506	3600
22	47	35	25	16	09	04
24	50	38	28	19	12	07
26	53	41	31	22	15	10
28	56	44	34	25	18	14
30	3159	3247	3337	3428	3521	3617
32	62	50	40	31	25	20
34	65	53	43	34	28	23
36	68	56	46	37	31	26
38	71	59	49	40	34	30
40	3773	3262	3352	3443	3537	3633
42	76	65	55	46	40	36
44	79	68	58	49	43	39
46	82	71	61	53	47	43
48	85	74	64	56	50	46
50	3188	3277	3367	3459	3553	3649
52	91	80	70	62	56	52
54	94	83	73	65	59	56
56	97	86	76	68	62	59
58	3200	89	79	71	66	62

A Table of Meridional Parts.

Min.	Deg. 52	Deg. 53	Deg. 54	Deg. 55	Deg. 56	Deg. 57
0	3665	3764	3865	3968	4074	4183
2	69	68	69	72	78	86
4	72	72	72	75	81	90
6	75	75	75	78	85	94
8	78	78	78	82	88	97
10	3682	3780	3882	3986	4092	4201
12	85	84	85	89	96	05
14	88	87	89	93	4100	09
16	91	91	92	96	03	12
18	95	94	95	4000	06	16
20	3698	3797	3899	4003	4110	4220
22	3701	3801	3902	07	14	23
24	05	04	06	10	17	27
26	08	07	09	14	21	32
28	11	11	13	17	24	35
30	3714	3814	3916	4021	4128	4238
32	18	17	20	24	32	42
34	21	21	23	28	35	46
36	24	24	26	31	39	49
38	28	27	30	35	43	53
40	3731	3831	3933	4038	4146	4257
42	34	34	37	42	50	61
44	38	37	40	46	54	64
46	41	41	44	49	57	68
48	44	44	47	53	61	72
50	3747	3848	3951	4056	4164	4276
52	51	51	54	60	68	79
54	54	55	58	63	72	83
56	57	58	61	67	75	87
58	60	61	65	70	79	91

A Table of Meridional Parts.

Min.	Deg. 58	Deg. 59	Deg. 60	Deg. 61	Deg. 62	Deg. 63
0	4294	4409	4528	4649	4775	4905
2	98	13	32	54	80	10
4	4302	17	36	58	84	14
6	06	21	40	62	88	19
8	10	25	44	66	92	23
10	4313	4429	4548	4670	4797	4927
12	17	33	52	74	4801	32
14	21	37	56	78	05	36
16	25	41	60	83	10	41
18	29	45	64	87	14	45
20	4332	4448	4568	4691	4818	4950
22	36	52	72	95	22	54
24	40	56	76	99	27	59
26	44	60	80	4704	31	63
28	48	64	84	08	35	67
30	4352	4468	4588	4712	4840	4972
32	55	72	92	16	44	76
34	59	76	96	20	48	81
36	63	80	4600	24	53	85
38	67	84	04	29	57	90
40	4371	4488	4608	4733	4861	4994
42	75	92	13	37	66	99
44	78	96	17	41	70	5003
46	82	4500	21	46	75	08
48	86	04	25	50	80	12
50	4390	4508	4629	4754	4883	5017
52	94	12	33	58	88	22
54	98	16	37	63	92	26
56	4402	20	41	67	96	31
58	05	24	45	71	4901	35

A Table of Meridional Parts.

<i>Min.</i>	<i>Deg.</i> 64	<i>Deg.</i> 65	<i>Deg.</i> 66	<i>Deg.</i> 67	<i>Deg.</i> 68	<i>Deg.</i> 69
0	5040	5179	5324	5474	5631	5795
2	44	84	29	80	37	5801
4	49	89	34	85	42	06
6	53	93	39	90	47	12
8	58	98	44	95	53	18
10	5063	5203	5349	5500	5658	5823
12	67	08	54	05	64	29
14	72	12	59	10	69	34
16	78	17	64	15	74	40
18	81	22	69	20	80	46
20	5086	5227	5373	5526	5685	5851
22	90	32	78	31	91	57
24	95	36	83	37	96	63
26	5100	41	88	42	5701	68
28	04	46	93	47	07	74
30	5109	5251	5398	5552	5712	5880
32	14	56	5403	57	18	86
34	18	61	09	63	23	91
36	23	65	14	68	29	97
38	27	70	19	73	34	5903
40	5132	5275	5424	5578	5740	5909
42	37	80	29	84	45	14
44	42	85	34	89	51	20
46	46	90	39	94	56	26
48	51	95	44	99	62	32
50	5156	5299	5449	5605	5767	5937
52	60	5304	54	10	73	43
54	65	09	59	15	78	49
56	70	14	64	21	84	55
58	74	19	69	26	90	61

A Table of Meridional Parts.

Min.	Deg. 70	Deg. 71	Deg. 72	Deg. 73	Deg. 74	Deg. 75
0	5967	6146	6336	6535	6747	6971
2	72	53	42	42	54	79
4	78	59	49	49	61	87
6	84	65	55	56	69	95
8	90	71	62	63	76	7003
10	5996	6177	6368	6570	6783	7010
12	6002	83	75	77	91	18
14	08	90	81	84	98	26
16	14	96	88	90	6805	34
18	20	6202	94	97	13	42
20	6026	6208	6401	6605	6820	7050
22	32	15	08	11	27	58
24	38	21	14	18	35	65
26	43	27	21	25	42	73
28	49	34	27	32	50	81
30	6055	6240	6434	6639	6857	7089
32	61	46	41	47	65	97
34	67	52	47	54	72	7105
36	73	59	54	61	80	13
38	79	65	61	68	87	21
40	6085	6271	6468	6675	6895	7130
42	92	78	74	82	6903	38
44	98	84	81	89	10	46
46	6104	91	88	96	18	54
48	10	97	94	6703	25	62
50	6116	6303	6501	6711	6933	7170
52	22	10	08	18	41	78
54	28	16	15	25	48	87
56	34	23	22	32	56	95
58	40	29	28	39	64	7203

A Table of Meridional Parts.

Min.	Deg. 76	Deg. 77	Deg. 78	Deg. 79	Deg. 80	Deg. 81
0	7211	7469	7746	8047	8377	8741
2	20	78	56	58	89	54
4	28	86	65	69	8400	67
6	36	95	75	79	12	80
8	45	7504	85	89	24	93
10	7253	7513	7795	8100	8435	8806
12	61	22	7804	11	47	19
14	70	31	14	22	59	32
16	78	40	24	32	71	45
18	87	50	34	43	83	59
20	7295	7559	7844	8154	8494	8872
22	7303	68	54	65	8506	85
24	12	77	64	76	18	98
26	20	86	74	87	30	8912
28	29	95	84	98	42	25
30	7338	7605	7894	8208	8555	8939
32	46	14	7904	19	67	52
34	55	23	14	31	79	66
36	63	32	24	42	91	80
38	72	42	34	53	8603	93
40	7381	7651	7944	8264	8616	9007
42	89	61	54	75	28	21
44	98	70	65	86	41	35
46	7407	79	75	98	53	49
48	16	89	85	8309	65	63
50	7424	7698	7995	8320	8678	9077
52	33	7708	8006	31	91	91
54	42	17	16	43	8703	9105
56	51	27	27	54	16	20
58	60	37	37	66	29	34

A Table of Meridional Parts.

Min.	Deg. 82	Deg. 83	Deg. 84	Deg. 85	Deg. 86
0	9148	9609	10148	10770	11539
2	63	25	160	793	568
4	77	42	179	816	597
6	92	59	199	839	626
8	9206	75	218	863	656
10	9221	9692	10238	10886	11686
12	36	9709	258	910	716
14	50	26	278	934	746
16	65	43	298	958	777
18	80	60	318	983	808
20	9295	9777	10338	11007	11839
22	9310	95	358	032	870
24	25	9812	378	058	902
26	40	30	399	082	934
28	56	47	420	107	967
30	9371	9865	10441	11133	11999
32	86	82	462	158	032
34	9402	9900	483	184	066
36	17	18	504	210	099
38	33	36	526	236	133
40	9449	9954	10547	11263	12167
42	64	73	569	289	202
44	80	9992	590	316	237
46	96	10009	612	343	273
48	9512	028	634	371	308
50	9528	10046	10656	11398	12344
52	44	065	679	426	381
54	60	084	701	454	408
56	76	103	724	482	445
58	93	122	747	410	483

A Table of Meridional Parts.

<i>Min.</i>	<i>Deg.</i> 87	<i>Deg.</i> 88	<i>Deg.</i> 89
0	12521	13920	16317
2	559	978	435
4	598	14037	557
6	638	097	683
8	678	158	814
10	12718	14220	16950
12	759	284	17092
14	800	348	240
16	842	414	394
18	884	481	556
20	12027	14550	17726
22	970	619	904
24	13014	691	18093
26	059	764	292
28	104	838	503
30	13150	14914	18729
32	196	992	971
34	243	15071	19230
36	294	152	511
38	339	236	817
40	13388	15322	20152
42	437	409	524
44	488	499	941
46	539	591	21416
48	591	686	967
50	13643	15783	22623
52	697	409	23435
54	751	499	24499
56	807	591	26046
58	863	686	28911

A N D now according to my promise, Page 868, I shall exhibit a Method of making a Scale to measure Distances on the *Mercator's* Chart, which may by the following Example be made for any Chart, if the extreme Latitudes of the Chart be given.

Example. Let it be required to make a Scale for a *Mercator's* Chart from Latitude 32 to Latitude 50, either North or South, and to contain 100 Leagues or 300 Miles Distance. (*See Plate XI. Fig. D.*)

F I R S T, find the Length of 300 Miles in the least Latitude (which here is 32) thus, As Sine Comp. Lat. 32° , To Radius; So is 300 Miles (the length of your Scale) To $354'$ or $5^{\circ} 54'$, which taken off the graduated line of Longitude, let it be the Length of the lowest line of the Scale 32 32, upon the middle of which line (at 50) raise the Perpendicular 50.50, subtract the Natural Secant of the least Latitude 32° , from the Natural Secant of the greatest Latitude 50° , and the Remainder 3766 taken from a Scale of equal Parts, set from 50 to 50 upwards upon the foresaid Perpendicular; and thro' 50 draw the uppermost line at right Angles with the Perpendicular, and Parallel to the bottom line 32.32, that line represents the Parallel of 50° . Then having found by the foregoing Proportion the length of 300 Miles, in Latitude 50° , which is $467'$, or $7^{\circ} 47'$; take half thereof, viz. $3^{\circ} 53\frac{1}{2}'$ from the graduated line of Longitude, and set it both ways upon the foresaid Parallel of 50, from the middle of the line (where it is cut by the Perpendicular) to each end; so shall the distance between those two Marks be the Measure of 300 Miles in Lat. 50° . Then from the Extremities of the Top and Bottom lines, draw the Side lines, 50 32 and 50 32. Now to find the intermediate Parallels, subtract the Na-

tural Secant of the least Latitude 32, from the Natural Secant of each greater Latitude as 34 36 38, &c. to 50, the several Remainders taken in your Compasses from the same Scale of equal Parts, by which you measured the middle Perpendicular line, and set upon the same line from the line 32.32 upwards, shall determine the points in that line thro' which the several Parallels must pass; therefore thro' these Marks draw lines parallel to the line 32.32, they represent the several Parallels required. Then divide the uppermost and lowest Parallel each into 100 equal Parts, marking them both with 10, 20, 30, &c. and between those Divisions marked with the same Number, on each line, draw strait lines thro' the Scale; these Lines will also divide each Parallel into 100 equal Parts or Leagues upon which you may measure your Distance in any Parallel as before is taught.

THE use of the Scale is easy, the Distances being to be taken off according to the Latitude of that part of the Chart, which is to be measured thus, the line 32.32, is 100 Leagues or 300 Miles in the Parallel 32, and the line 50.50, is 300 Miles in the Parallel of 50 Degrees: But if (as is most common) the Ship sails upon an oblique Course, measure the Distance upon a parallel in the Scale that is nearest the middle parallel, between the two Extremes, and that is sufficiently exact.

Example. If the Ship has sailed in the North-East quarter from Latitude 42, to Latitude 46, the Distance is to be measured on that parallel of the Scale marked 44.44, &c.



CHAP. XL.

Of the chief Problem in Navigation; viz. To find in the Maps the Place to which a Ship is come after some sailing; or to find the Latitude and Longitude of that Place.

PROPOSITION I.

The Point to which a Ship is to be directed, cannot be known except we first know what Place the Ship is come to.

WE said, in the preceding Proposition, that the chief Problem in Navigation is how to find the Point to which a Ship is to be directed; and which 'tis plain cannot be known except we first know the Place from which the Ship is to be directed; and therefore the Solution of that Problem for finding the Ship's Place is necessary: and the Problem for finding the Point comes to this.

PROPOSITION II.

To find the Place to which a Ship is come after some time of sailing.

THE Dutch mark every Day with a Pin the Place in the Maps to which the Ship is come; and thence they may know which way to steer the Ship: and for this they use a three-fold Method, according to that which they judge is found most exactly.

Having observed the Point the Ship failed on the former Day, and the Way she hath made since, her present Place is thus found in the Maps: Take a Square, and apply one Leg to the Place from which the Ship came last, and the other to the Point or Line nearest it, on which the Ship failed, and mark with a Pin, or Pen, the Part of the Leg, which is above the Place left. Then take, from a Scale of Miles, the Miles run, and apply one Foot of the Compass to the Place left, and let the Scale be moved in the Line that shows the Point, 'till the other Foot reach the Point marked on the Square; the Place in the Map under that Point, in that Situation of the Square, is the Ship's Place.

SEAMEN use two pair of Compasses without a Square; but if you would determine the Ship's Place more accurately by Calculation; the Problem will be this: Having the Latitude and Longitude of the Place left, and the point failed on, with the Distance failed, to find the Latitude and Longitude of the Place come to; by which the Ship's Place may be marked more accurately in the Map.

2. THE Point the Ship hath failed on, and the Latitude she is come to, being known; to find her Place in the Map.

LET there be again applied one Leg of the Square, to the Point failed on, or one nearest it, and the other laid on the Place come from, and there make a mark with a Pin or Pen; then move the Leg applied to the Point failed on, 'till the marked Point on the other Leg come into the Parallel of the observed Latitude; and the Point where it cuts it, is the Ship's Place. If there be not a Parallel drawn thro' it, take with the Compasses the Degrees on the Margin between the next Parallel, and that Latitude; and at the same Time apply a Square

Sqaure in the Line of the Points, and setting one Foot on some Place of the Parallel, so as it's other may reach to the other Point, marked on the Leg, you have the Ship's Place. Or by Calculation the Problem is this: Having the Latitude and Longitude of the Place left, and the Latitude of the Place come to, and the Point sailed in, to find the Longitude which will give the Ship's Place.

3. KNOWING the Distance sailed, and the Latitude come to, to find the Ship's Place in the Map.

TAKE from the Scale, the Miles sailed, and if a Parallel pass thro' the Degree of Latitude, known by Observation; place one Foot of the Compasses on the Place known, and the other on the Parallel, and you have the Ship's Place: but if no Parallel pass thro' it, apply one Leg of the Square to the next Parallel, and on the other Leg mark the Degree of Latitude, and move the Square 'till the other Foot of the Compass touch the Point marked on the Ruler: the Place of the Map under that Point is the Ship's Place. By Calculation the Problem is this: Having the Latitude and Longitude of one Place, and the Distance of it from another, and the Latitude of that other; to find also it's Longitude, which will determine it's Situation on the Globe. There is a fourth Method also by having the Longitude of the Place come to, when it's Latitude is wanted; but because that seldom happens at Sea, we shall omit it. They that desire more of this, may read *Snellius*, *Stevinus*, *Metius*, and others, who have handled it largely.

PROPOSITION III.

To find nearly the Point a Ship sails in, tho' the Signs are fallacious.

IN the Solution of the former Proposition there was supposed, as known; (1) The Point sailed on, (2) The Distance sailed, (3) The Latitude of the Place come to: Now we are to show how these three are found at Sea: for if these are not found truly, the Ship's Place is not truly determined.

1. AS to the Point sailed on, Sailors know it by their Sea-Compass; for the Ship is supposed to describe the same Line that shows the Point. They seldom use the Method by the Place of the Sun's rising or setting by Culculation.

THESE Signs are subject to uncertainty; 1. If the Declination of the Needle be not known in that Place. 2. If there be a Current there, or as in many Places in the *Torrid Zone*, a general and constant Motion of the Sea, that will carry the Ship with it. 3. A Storm will drive the Ship out of the Line of Direction. 4. The Ebbing and Flowing of the Sea will carry the Ship with it. 5. Allowance is to be made for Lee Way, on account of the Waves that hinder the Ship's Motion that Way she is directed; for all which Reasons their Sea-Compass is not to be relied on, and the Correction of these is very imperfect.

PROPOSITION IV.

To find how many Miles the Ship hath sailed from a given Place.

THIS is but guessed at; 1. By knowing how far a Ship will sail in such a Time, with such a Wind.

2. If

2. If she sail in the same Meridian, or near it, the Difference of the Latitude of the Place left and come to, turned to Miles, gives the Distance sailed with that Wind, in that Time; and then the Ship sailing any other Way with that Wind makes the same Way in that Time. 3. With more Labour they find it by the Log-line, which is a Line fastned to a Log of Wood, and thrown out of the Ship's Stern, the Line being wound about a Wheel in the Ship's Cabin, which must turn to give more Rope while the Ship moves from the Log; they observe how many marked Fathoms of the Rope go out of the Ship in half a Minute, which will give her Motion in sixty Minutes, or one hundred and twenty Minutes and a half; each Mark that goes out will be a Mile in an Hour, if the Marks or Knots be fifty Foot distant. But these Methods are uncerain; for, 1. There is a Motion of the Sea in some Places to one Place, to which, if the Ship go, she moves the faster; if to the contrary, slower. 2. The Ship is carried by other Causes to other Points, and goes in several Lines. 3. The Winds frequently change. 4. The higher the Ship's Stern is, the Line winds off the Wheel the slower, and her Motion thereby seems the less.

PROPOSITION V.

To observe the Latitude of the Place come to.

THEY use the Sun by Day, and the Stars by Night, as in *Chap. 23*. They use three Sorts of Instruments for this Purpose, *viz.* an Astrolabe, Radius, and Triangle. The Latitude by these is determined more accurately than the Point sailed in, or the Miles sailed; tho' there is also an uncertainty on account of, first, the Ship's Motion, which hinders Observation; secondly, not applying
ing

ing the Eye right to the Instrument ; and, thirdly, the Refraction is not considered.

PROPOSITION VI.

From what precedes it appears, that the Methods which Sailors use to find the Ship's Place are in the Chart uncertain, on account of the uncertainty as to the Point sailed in, and of the Miles run, and of the observed Latitude ; yet the Observation of the Latitude of the Place come to, is less liable to Error, especially in calm Weather, and a clear Sky, and may be corrected.

BUT from this alone we cannot find the Ship's Place, but, as was at large delivered, in *Chap. xxx.* there must be another Datum, viz. either the Distance from the Place left, or Point sailed in, or the Difference of the Longitude left, and come to ; and therefore the Longitude of the Place come to, which, with the Latitude, is again wanted, determines the Ship's Place.

HENCE it appears, that the Art of Navigation is to be perfected by the Solution of this Problem ; *To find, at any Time, The Longitude of a Place at Sea.* A public Reward is promised for the Discovery ; let him obtain it who is able.

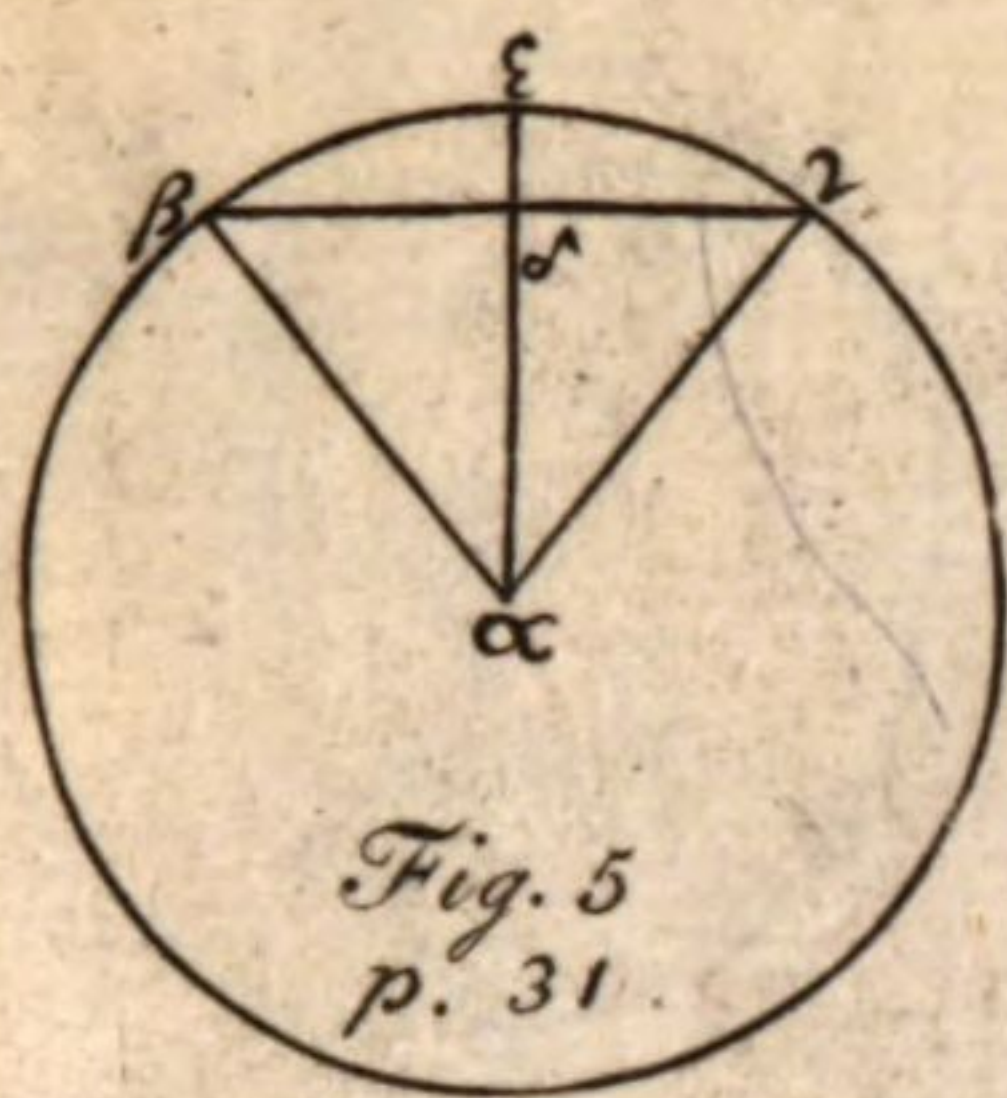


Fig. 5
p. 31.

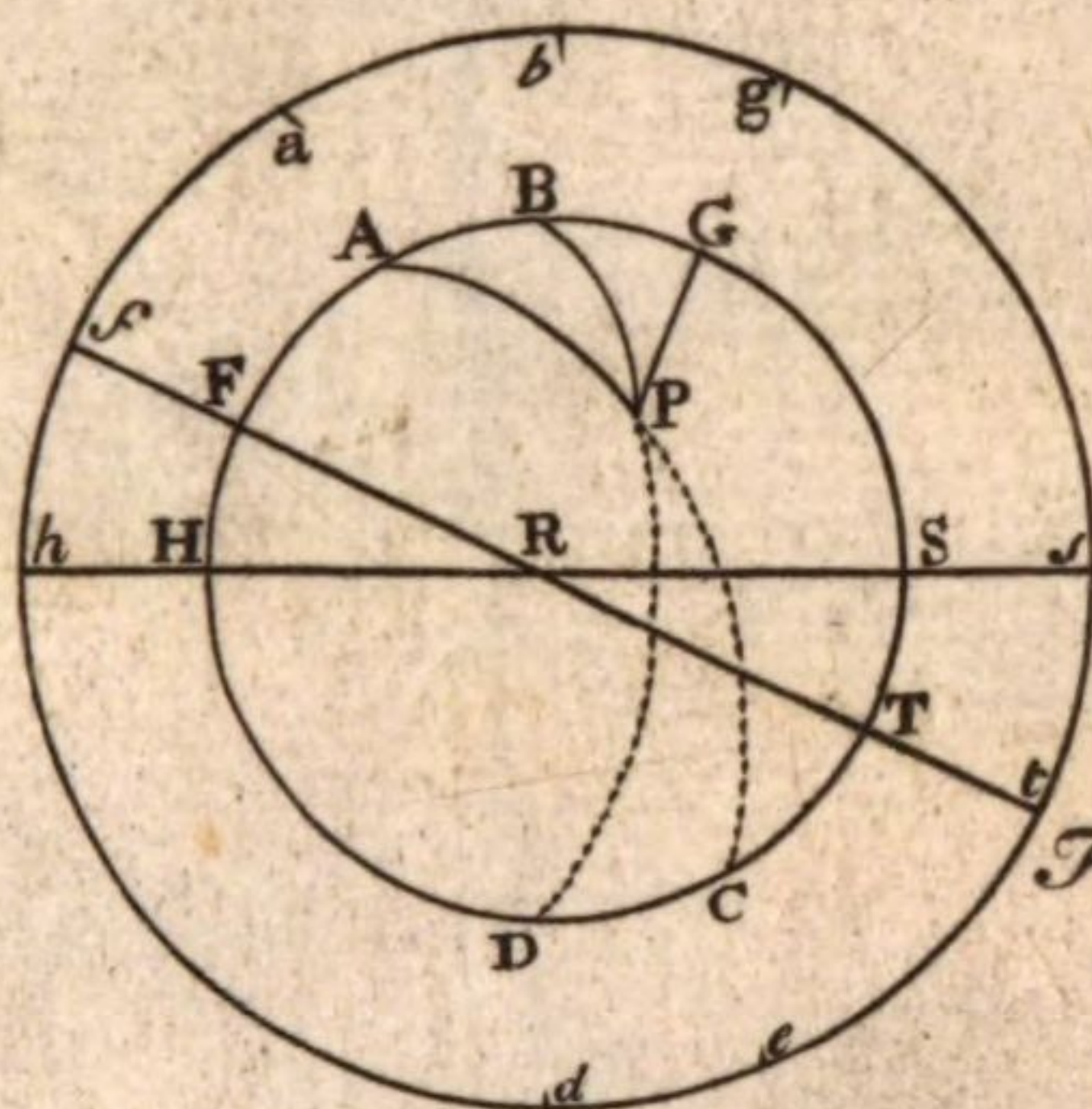


Fig. 6 p. 46.
48. 49.

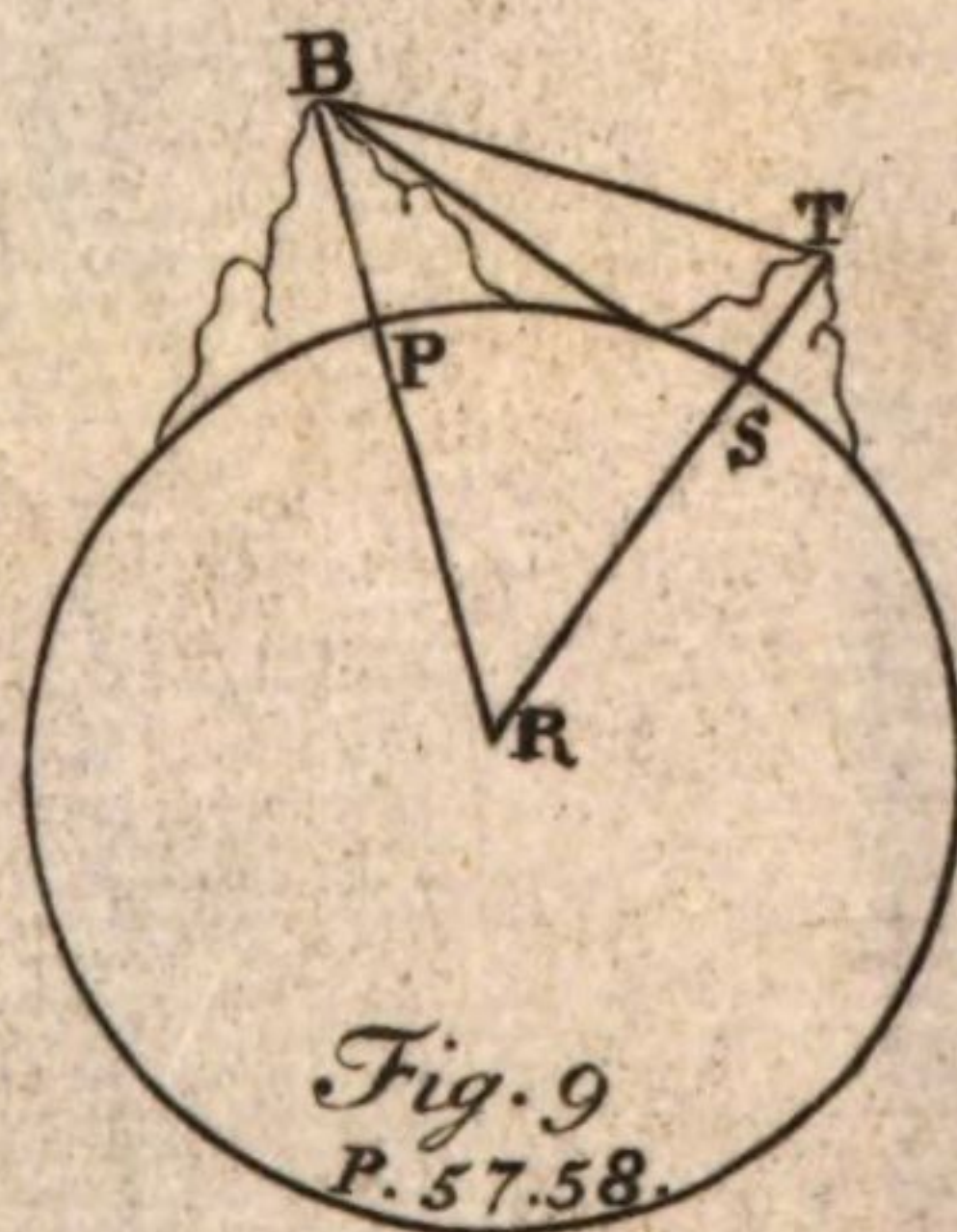


Fig. 9
P. 57. 58.

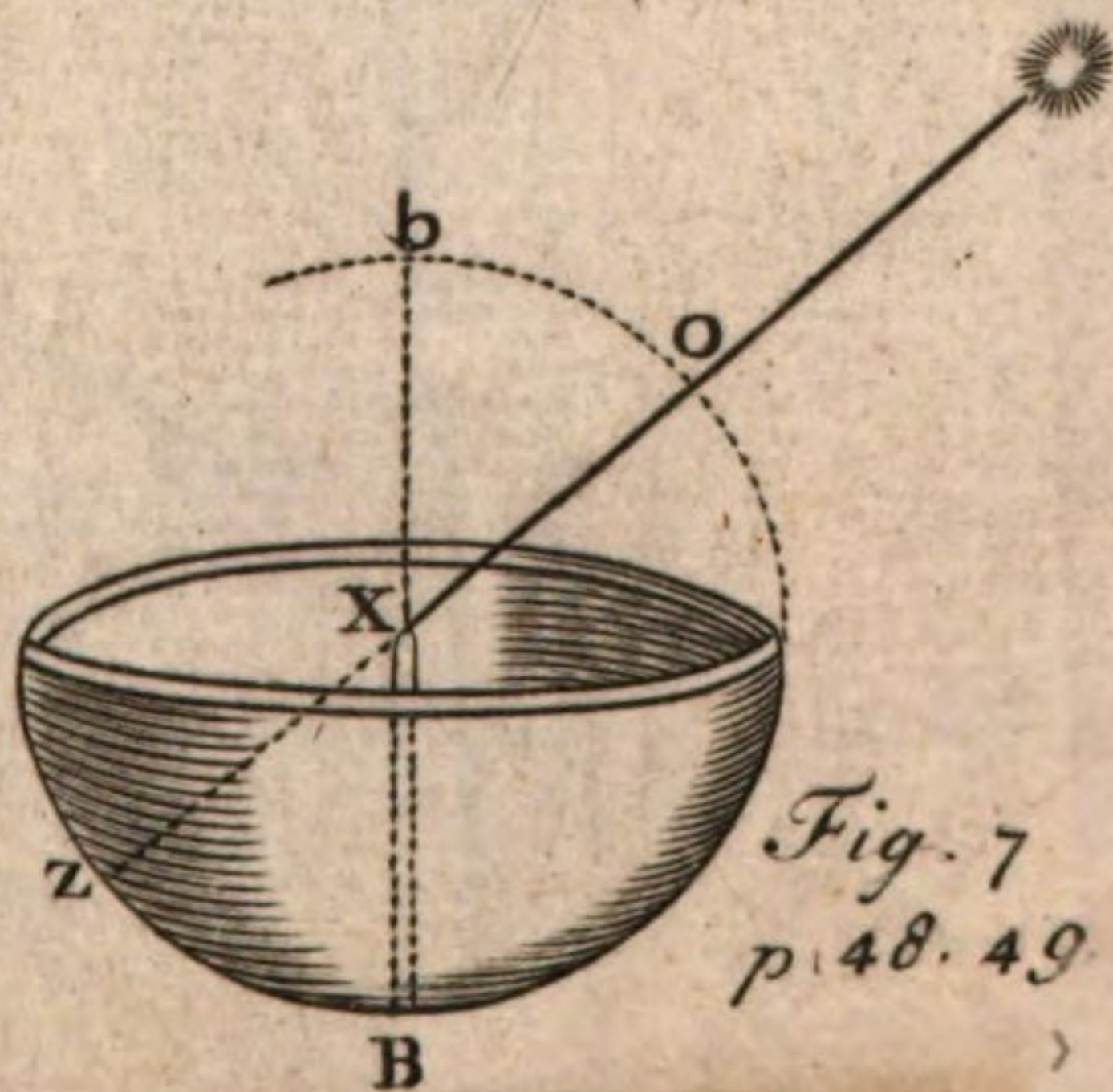
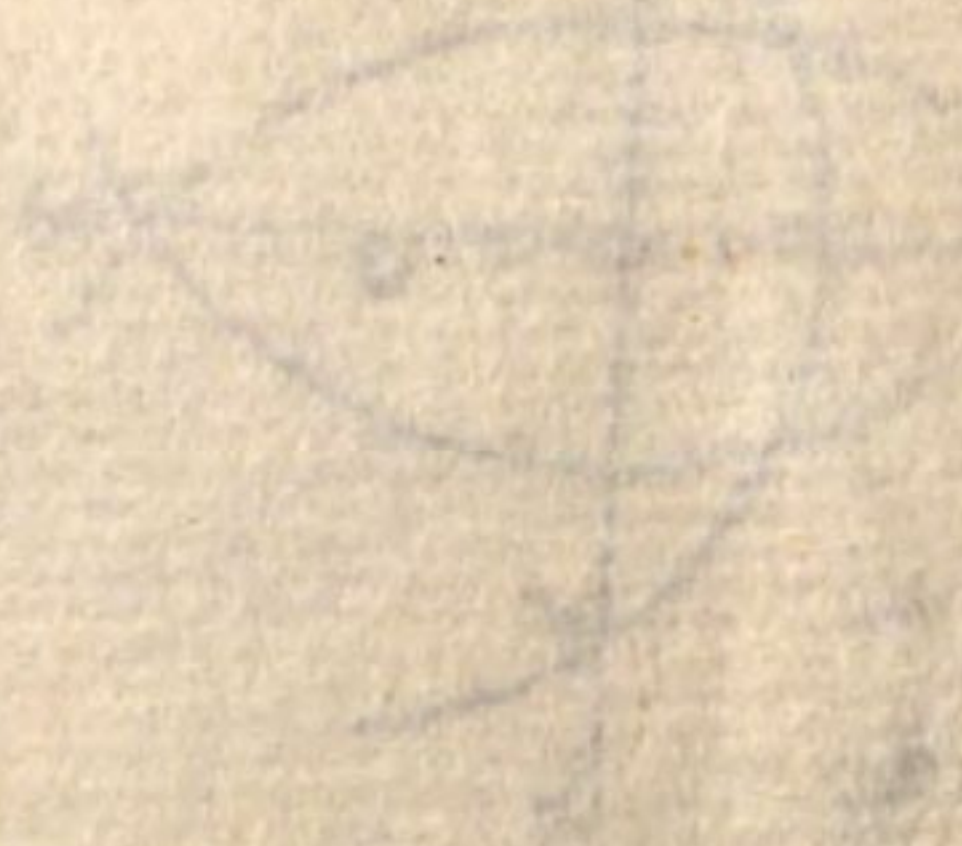
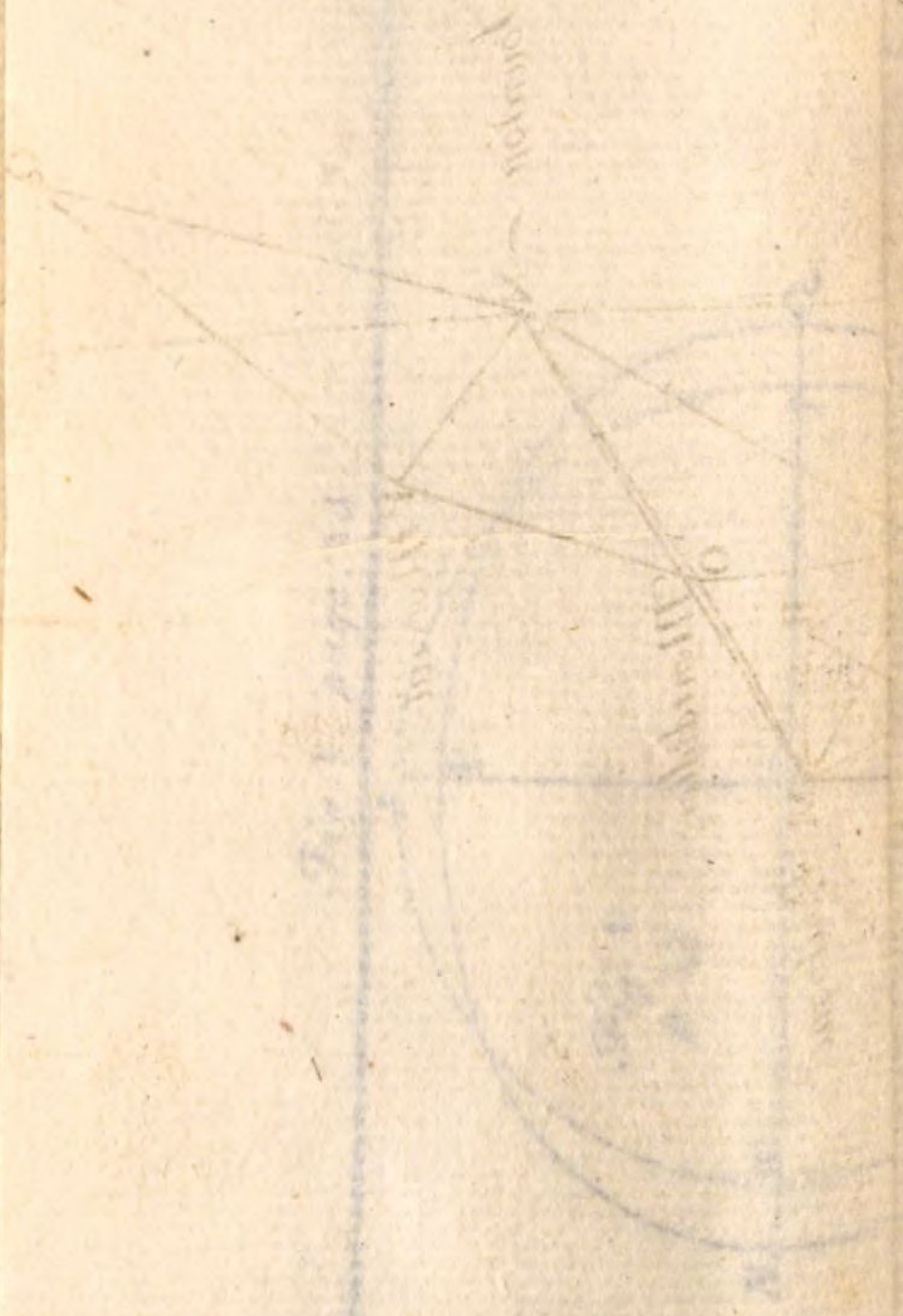
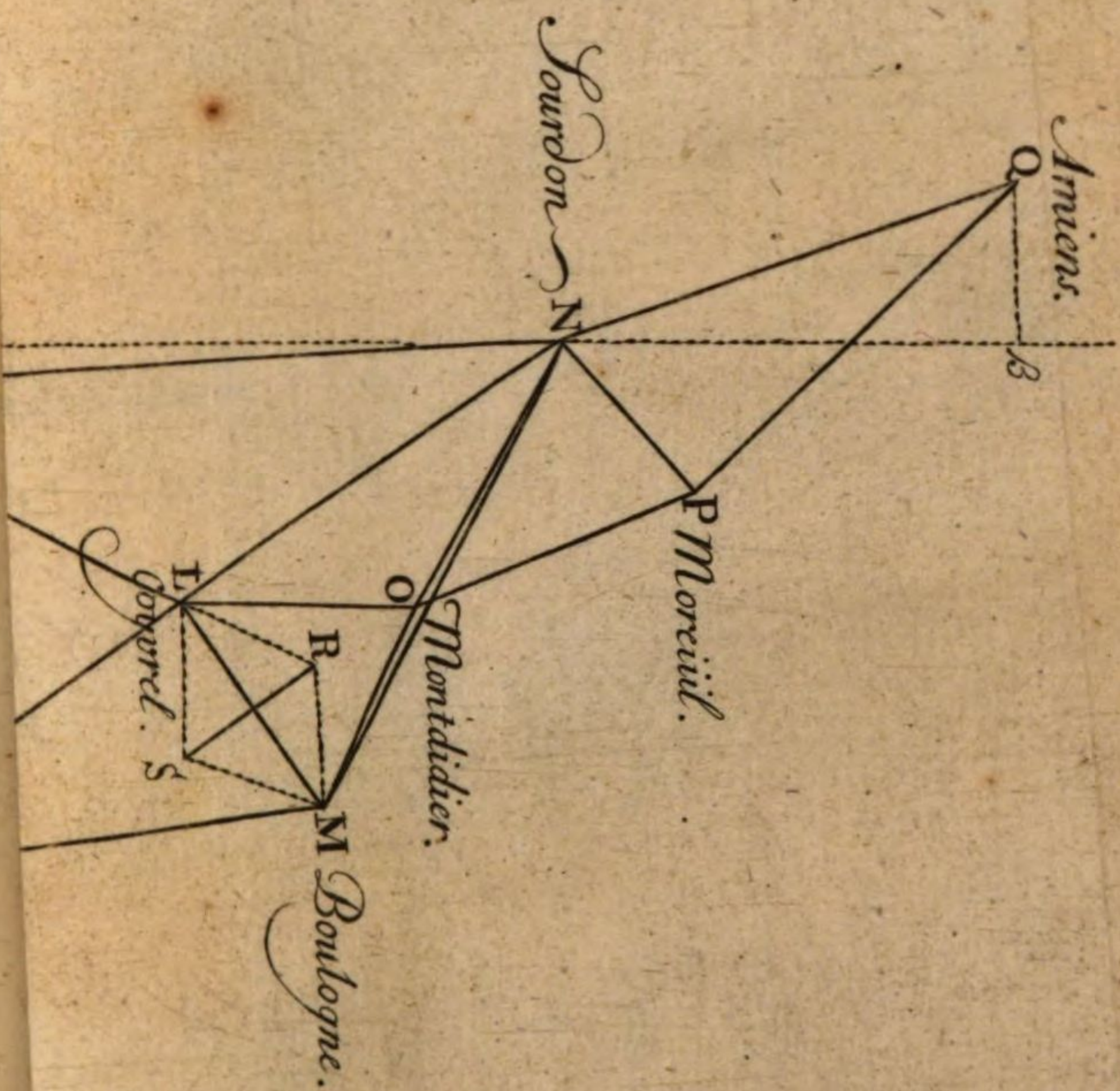


Fig. 7
p. 48. 49.

1819

1819





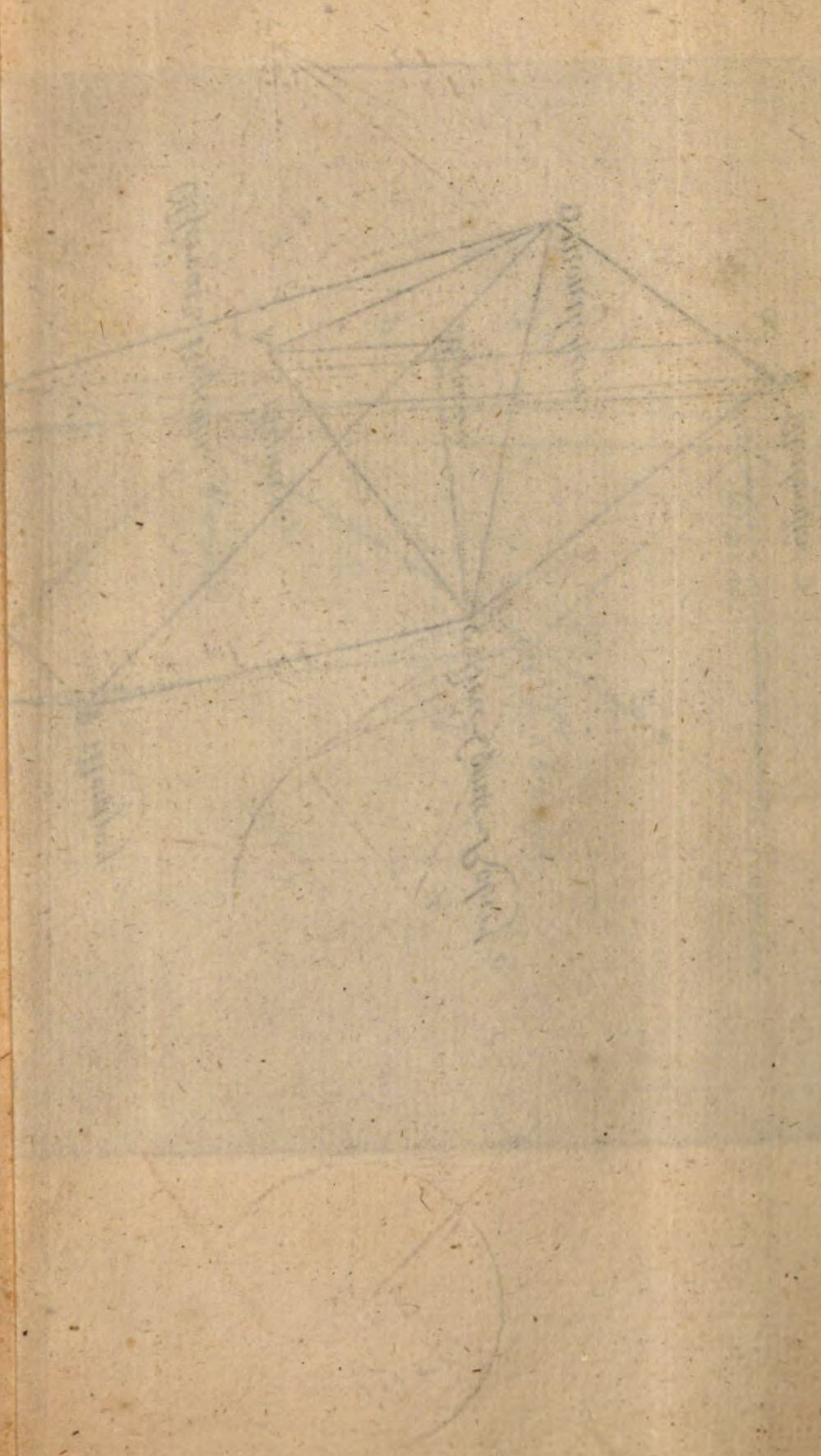


Fig. 12
& 13
p. 120. 123.

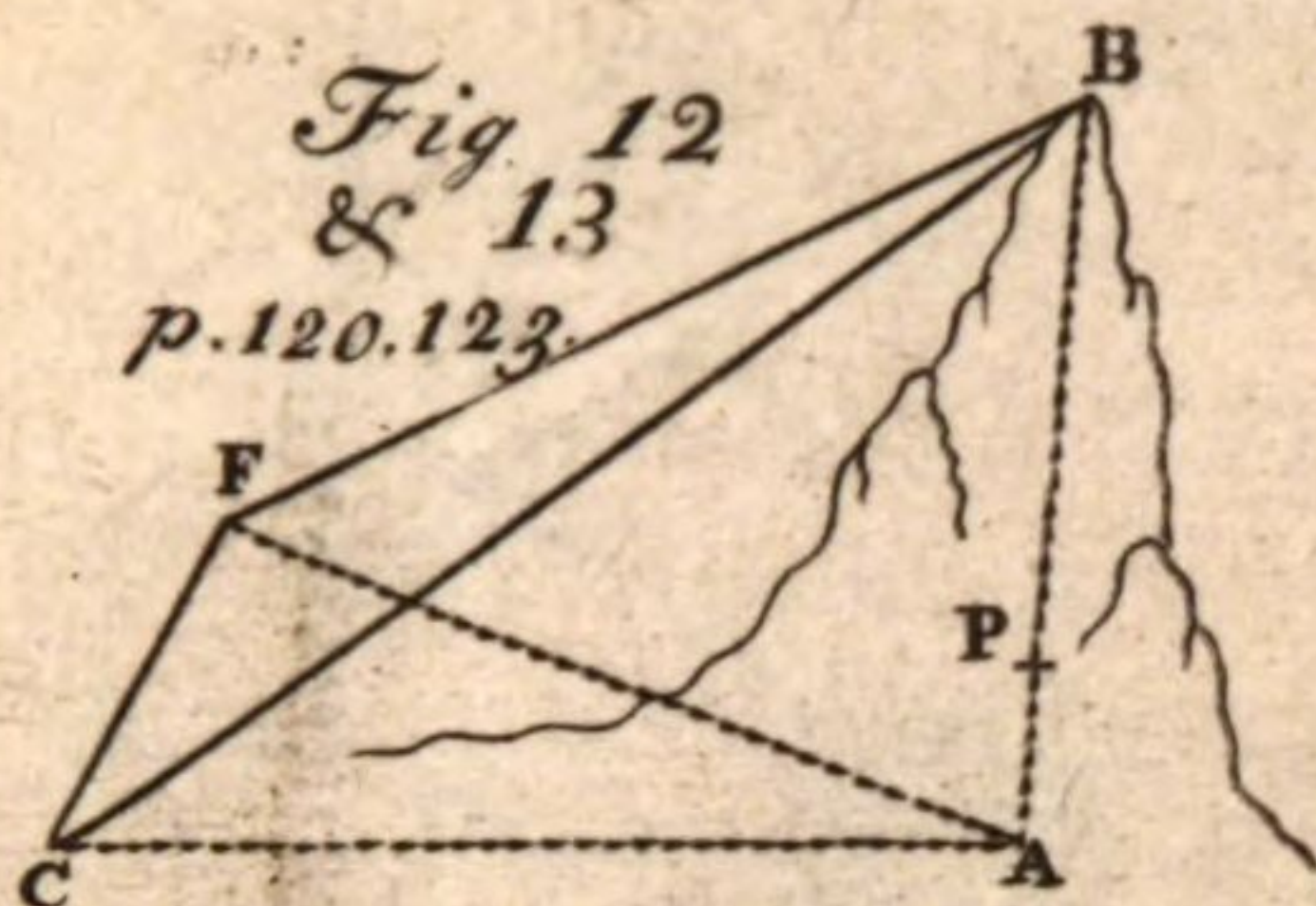


Fig. 14 p. 124.
126.

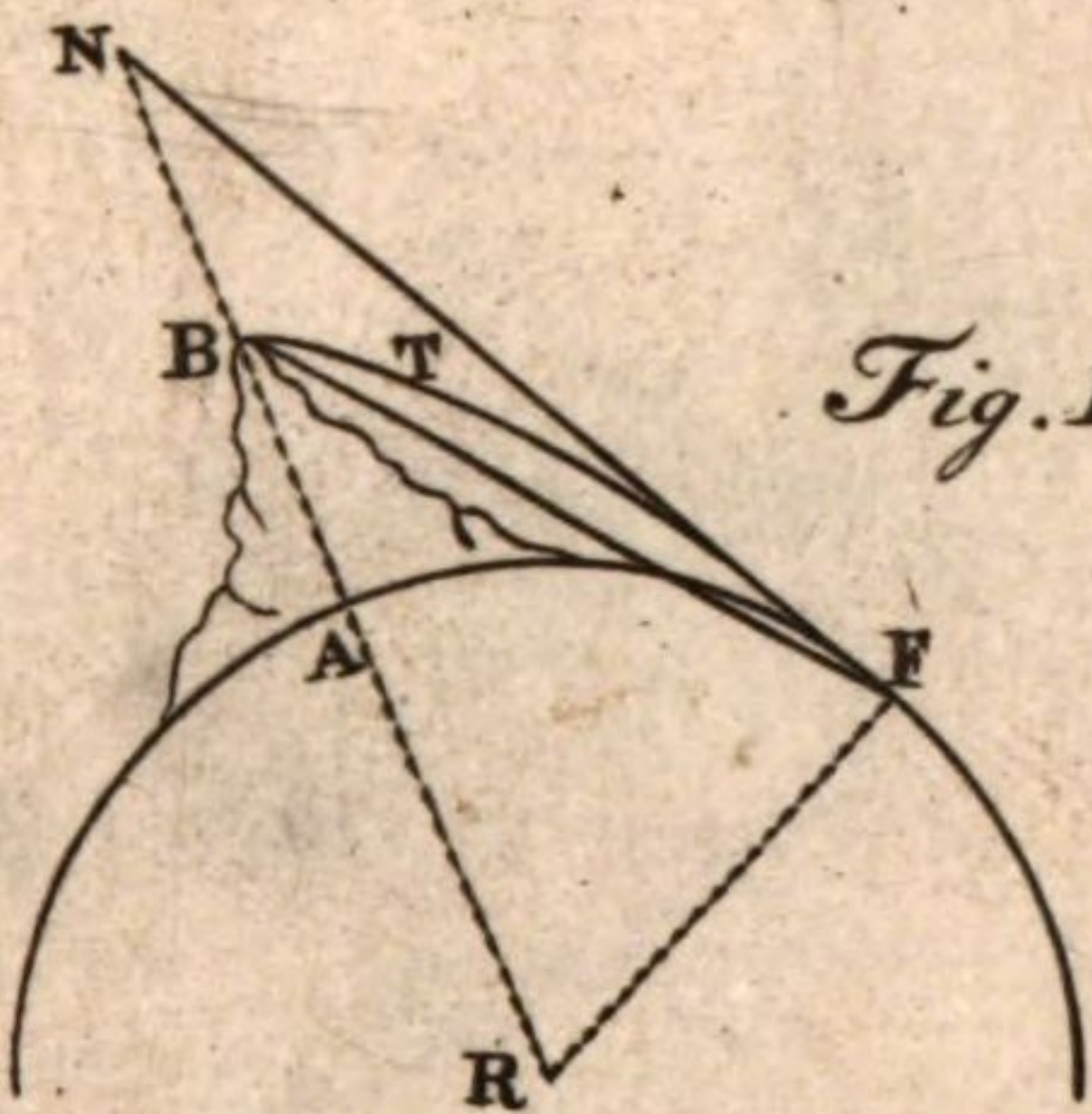
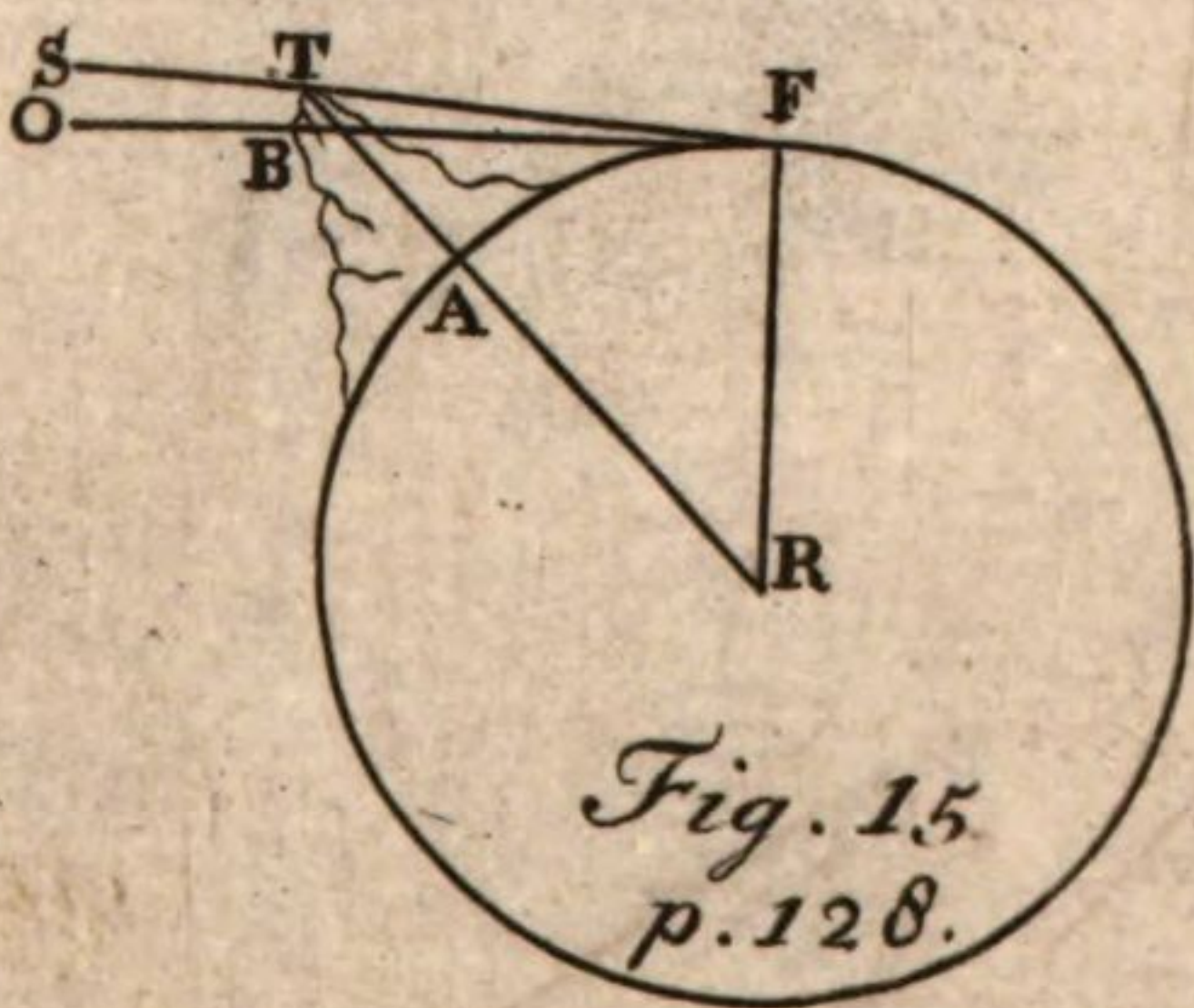


Fig. 15
p. 128.



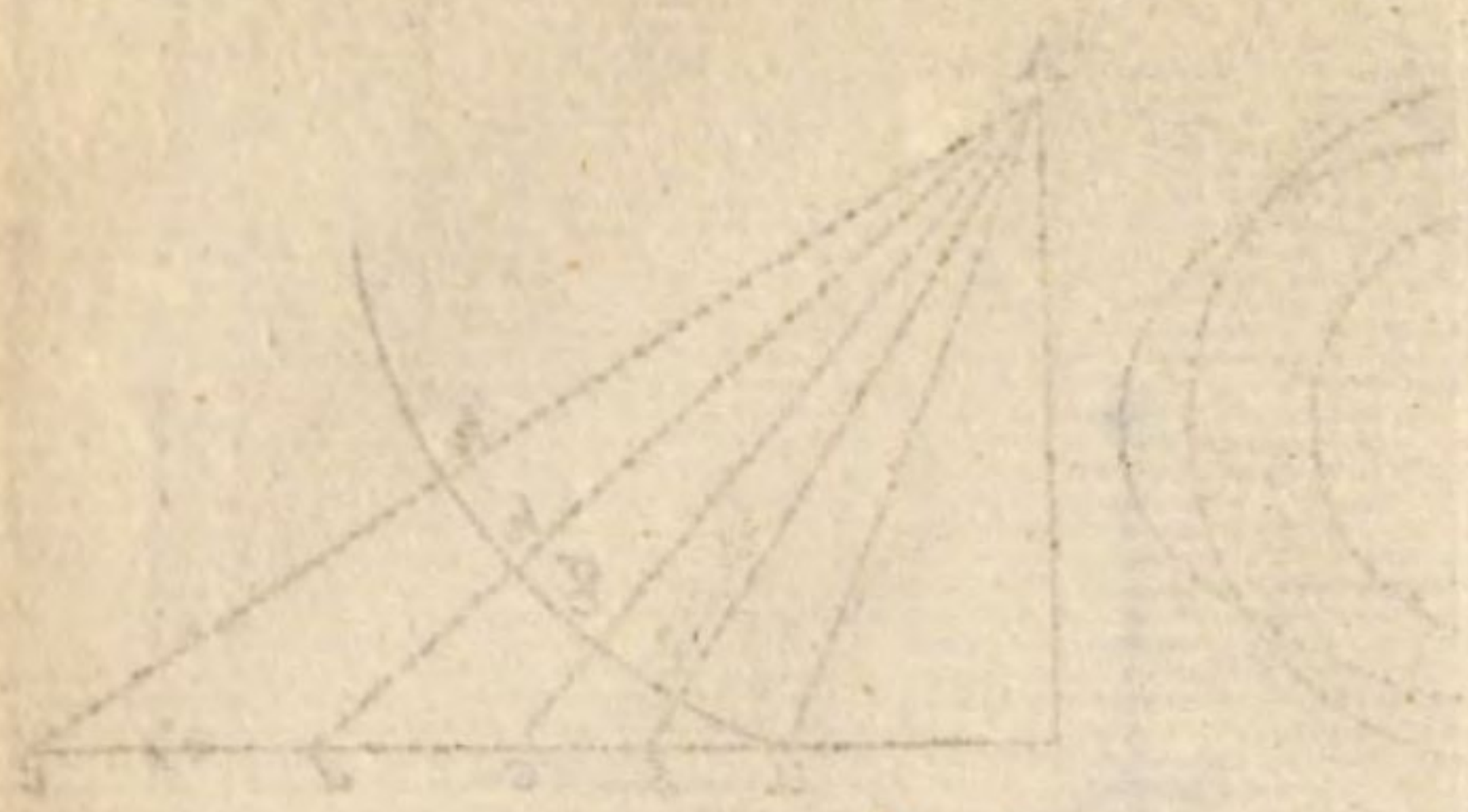


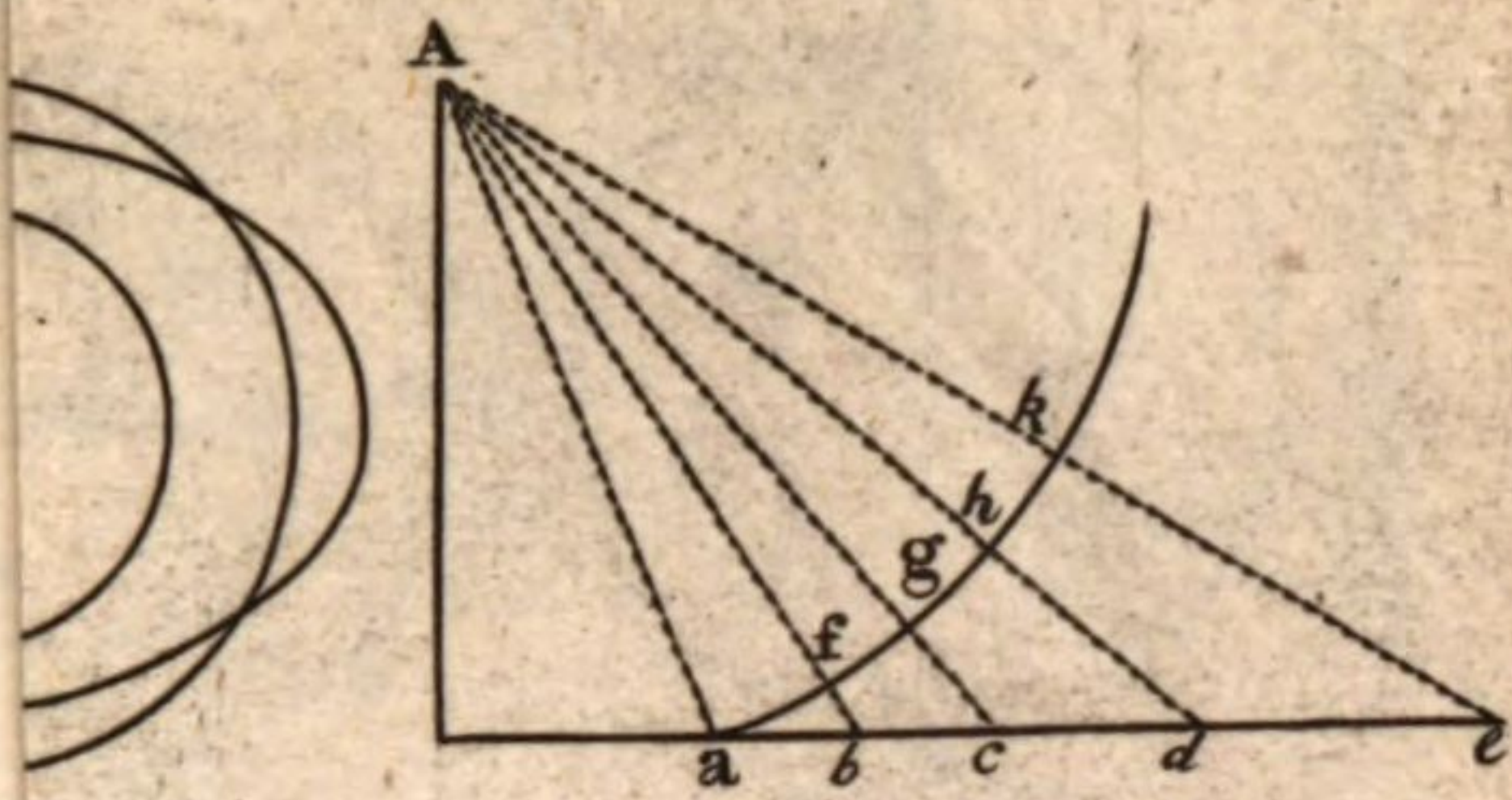
Fig. 8. p. 188.



Fig. 9. p. 189.



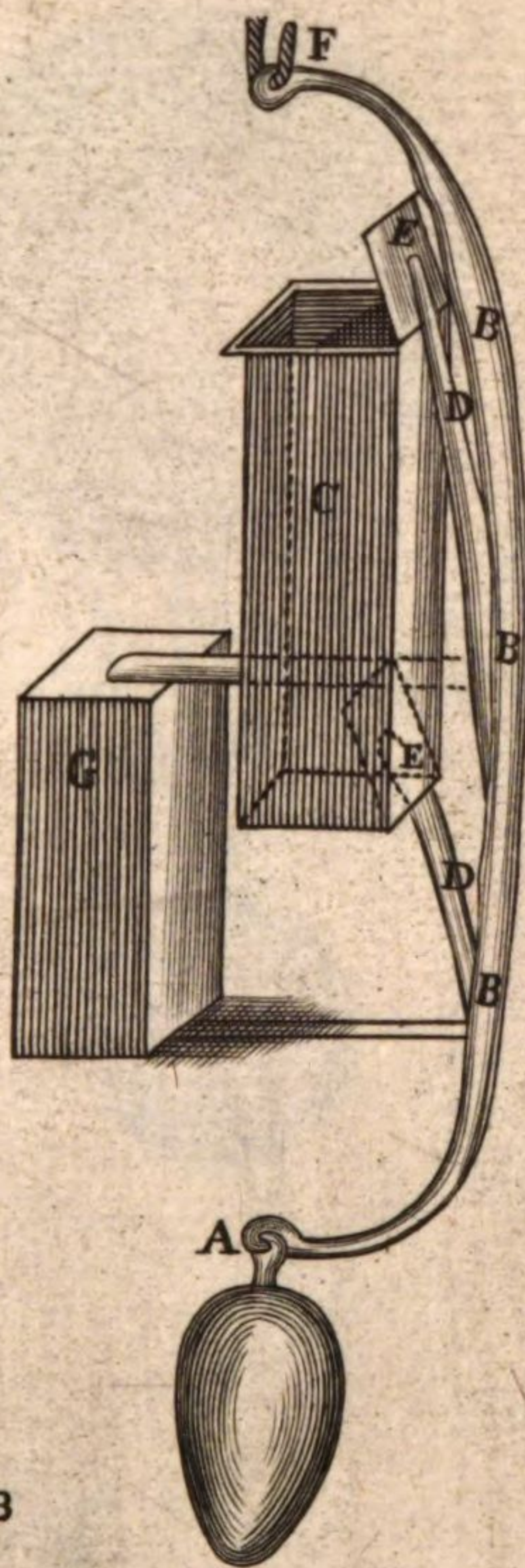
Fig. 10.



17 p.183.

Fig. 18 p.188.

Fig. 21
p. 213.





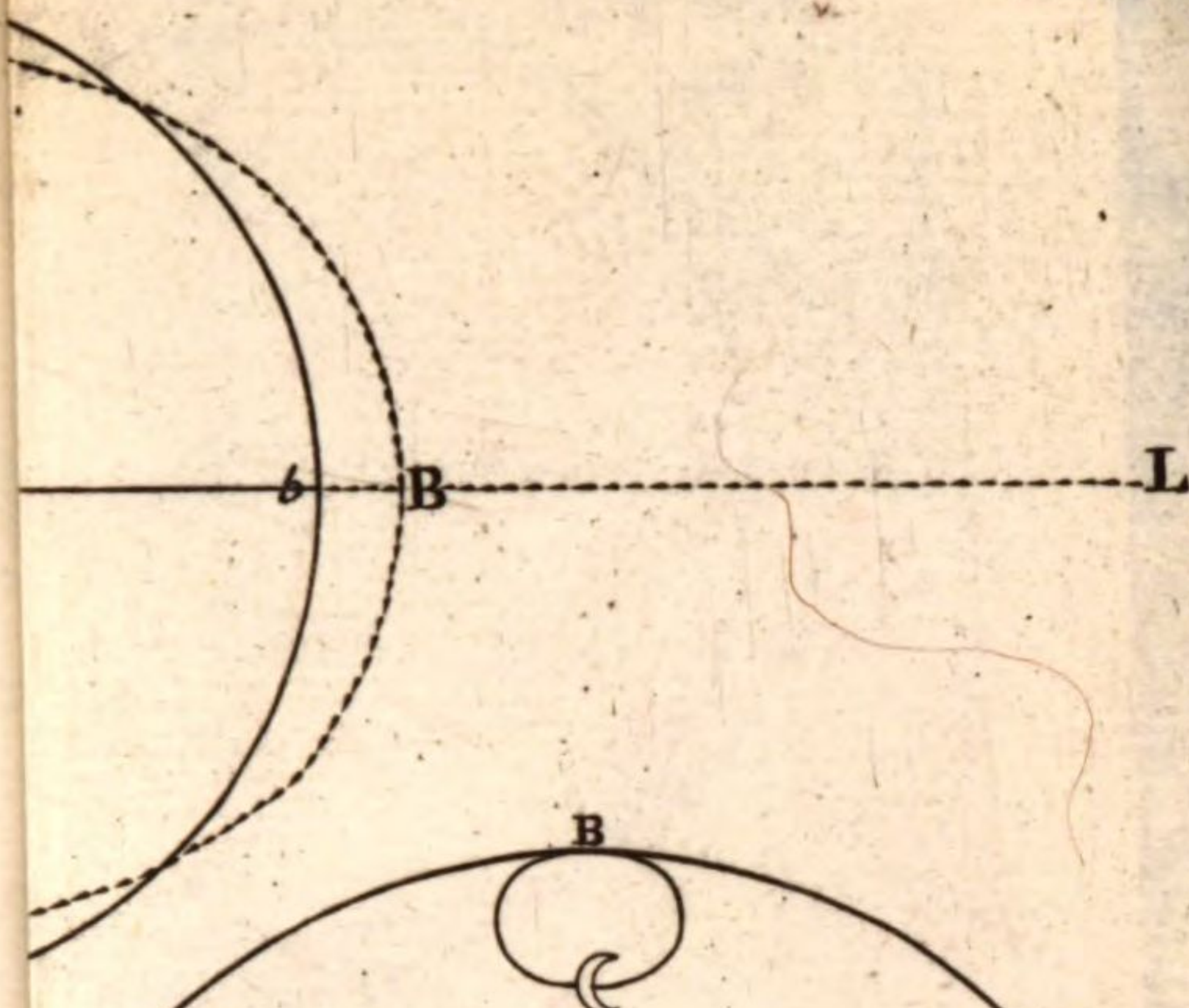
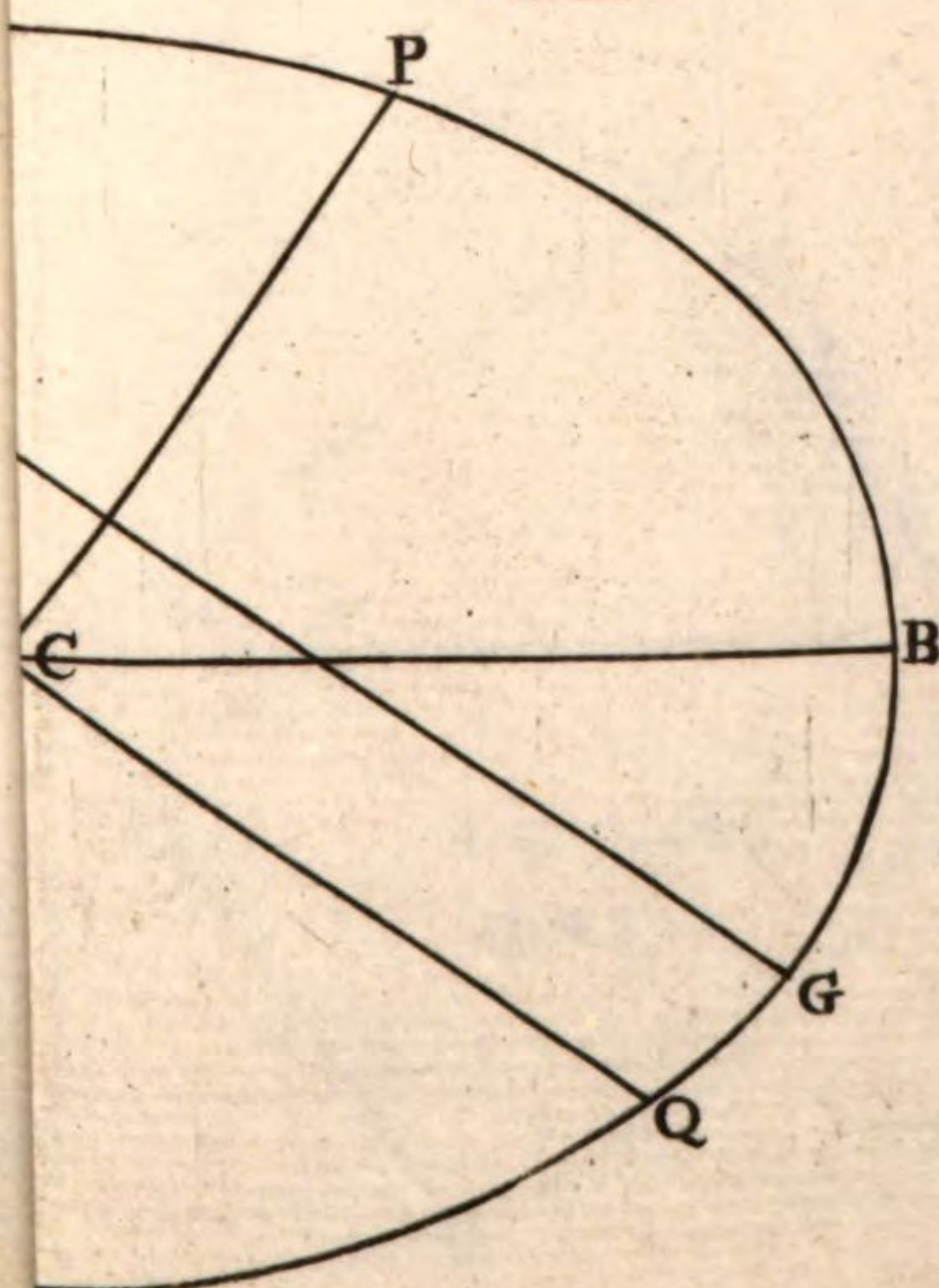
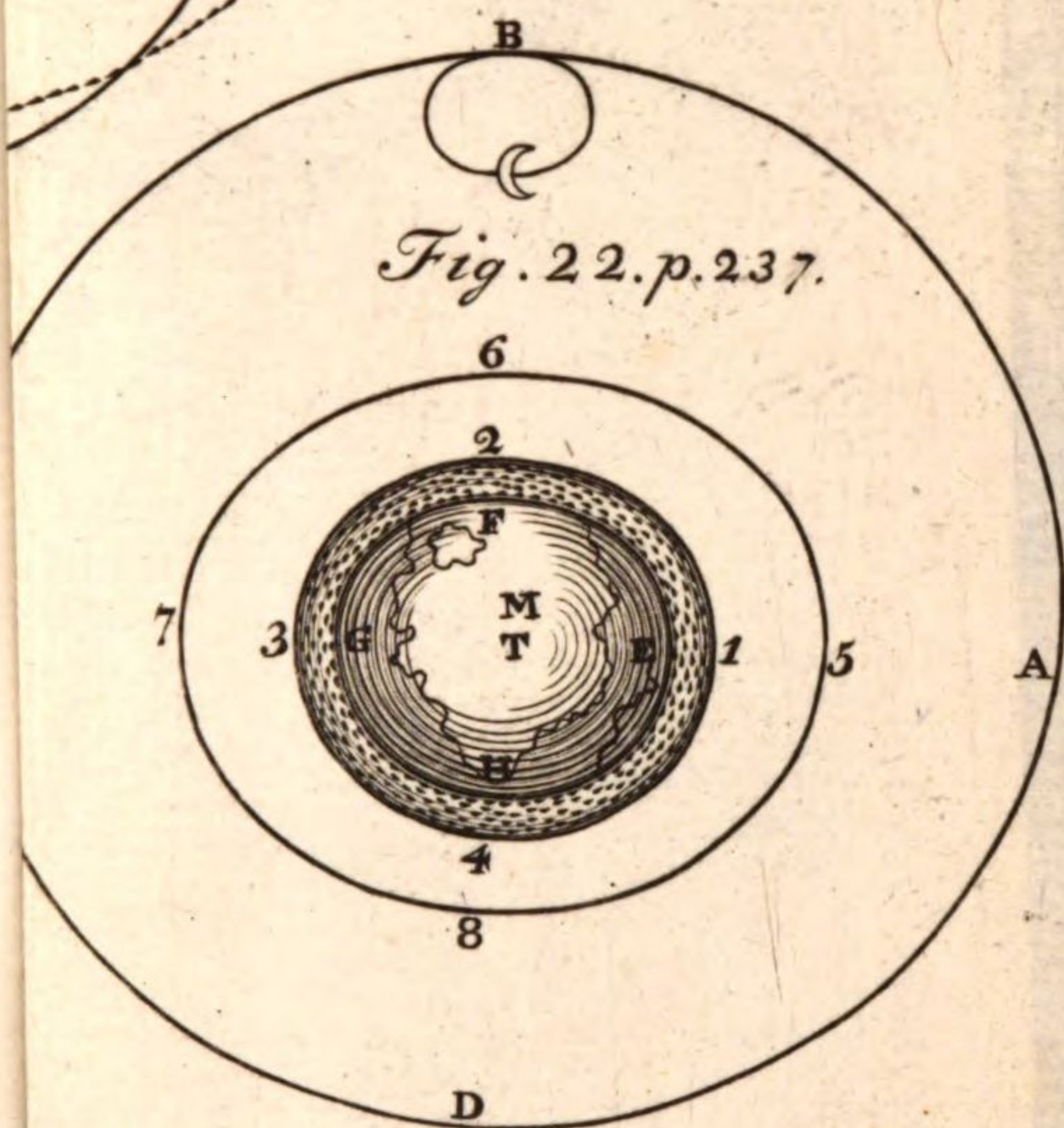


Fig. 22. p. 237.



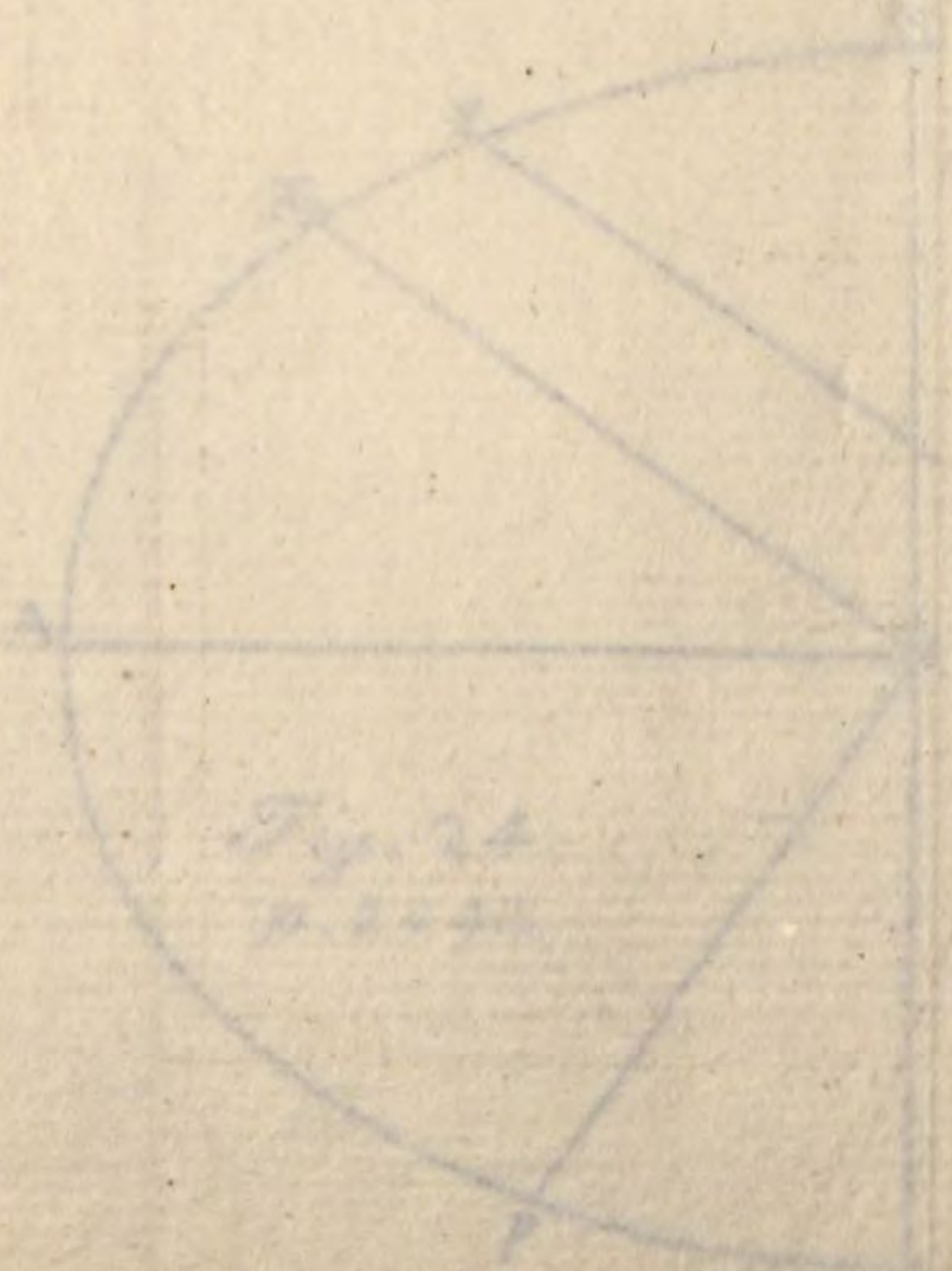
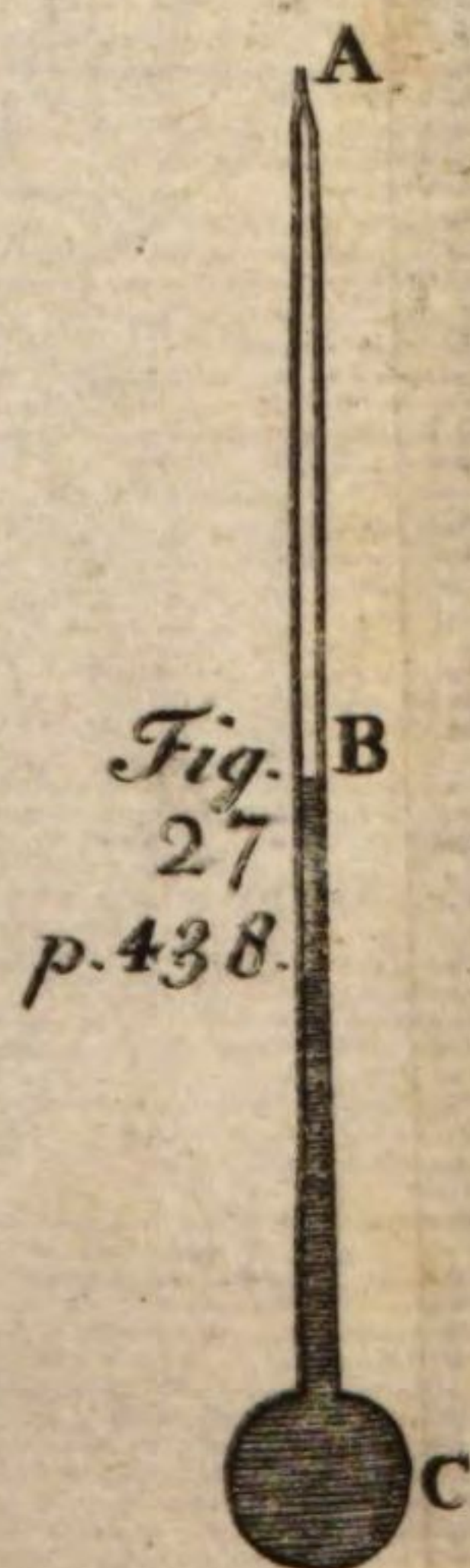
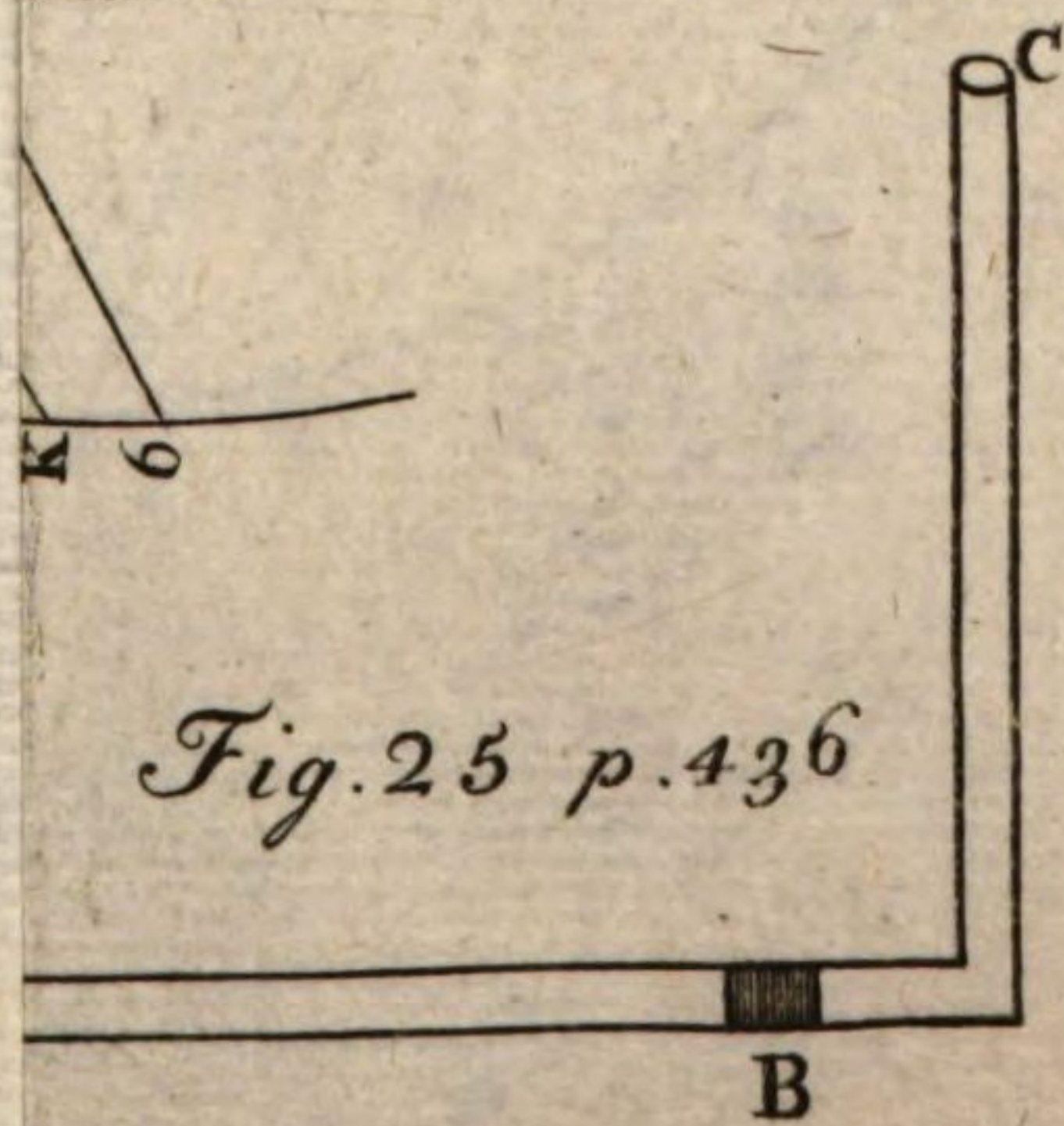
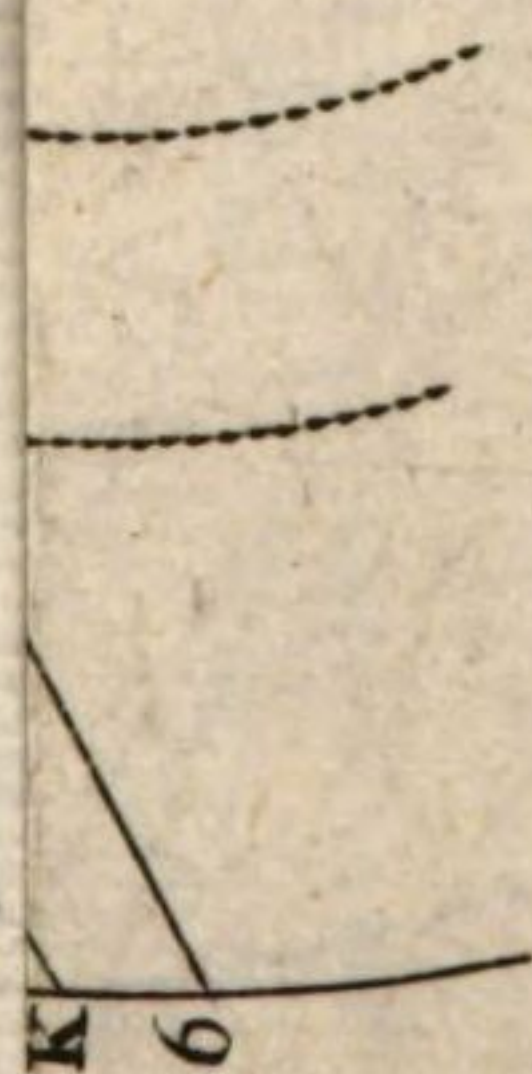
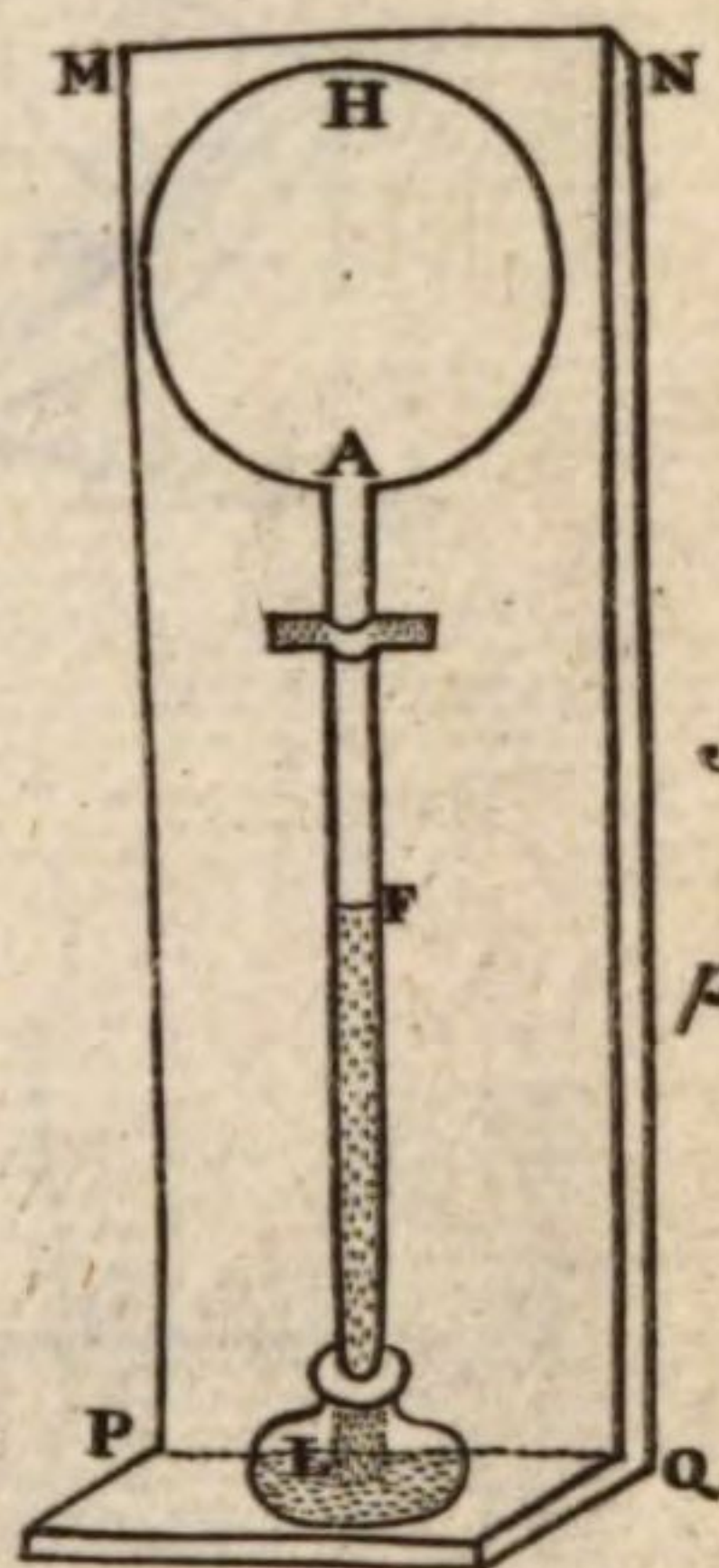
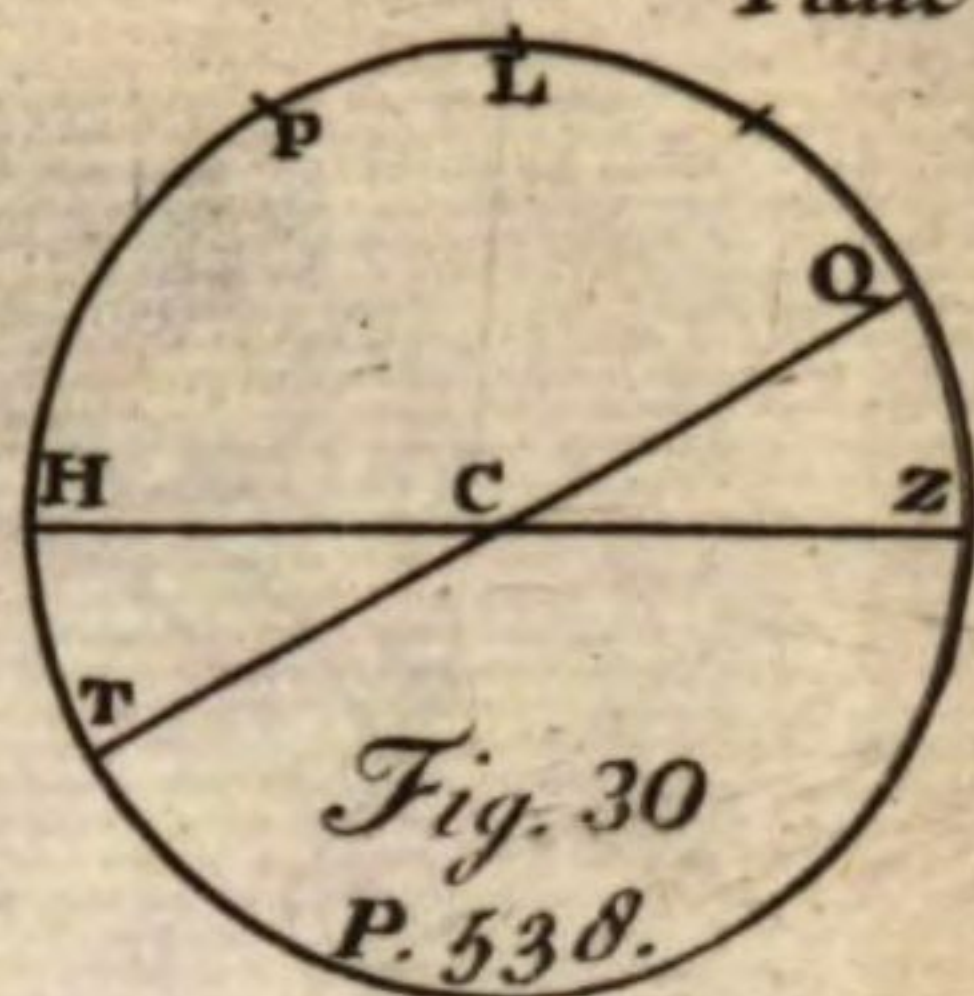


Fig. 24
p. 244



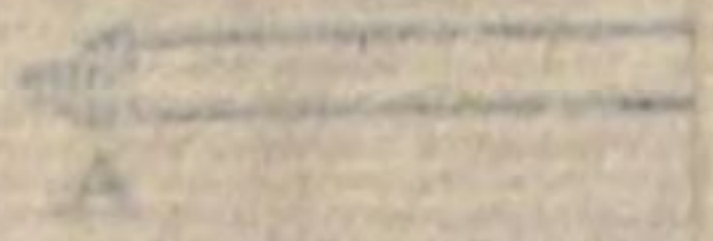


Fig: 30 see Page 494 Vol. I. Plate VI



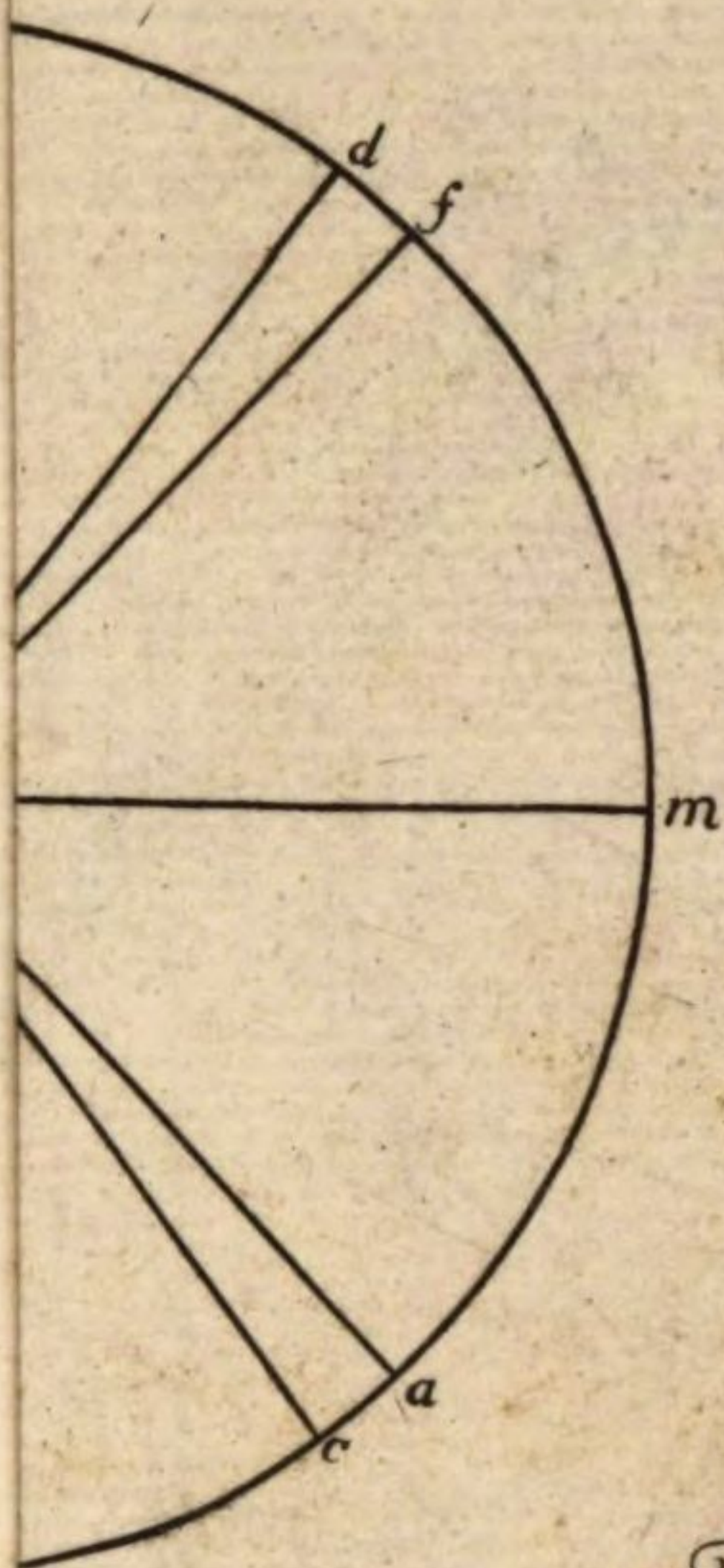
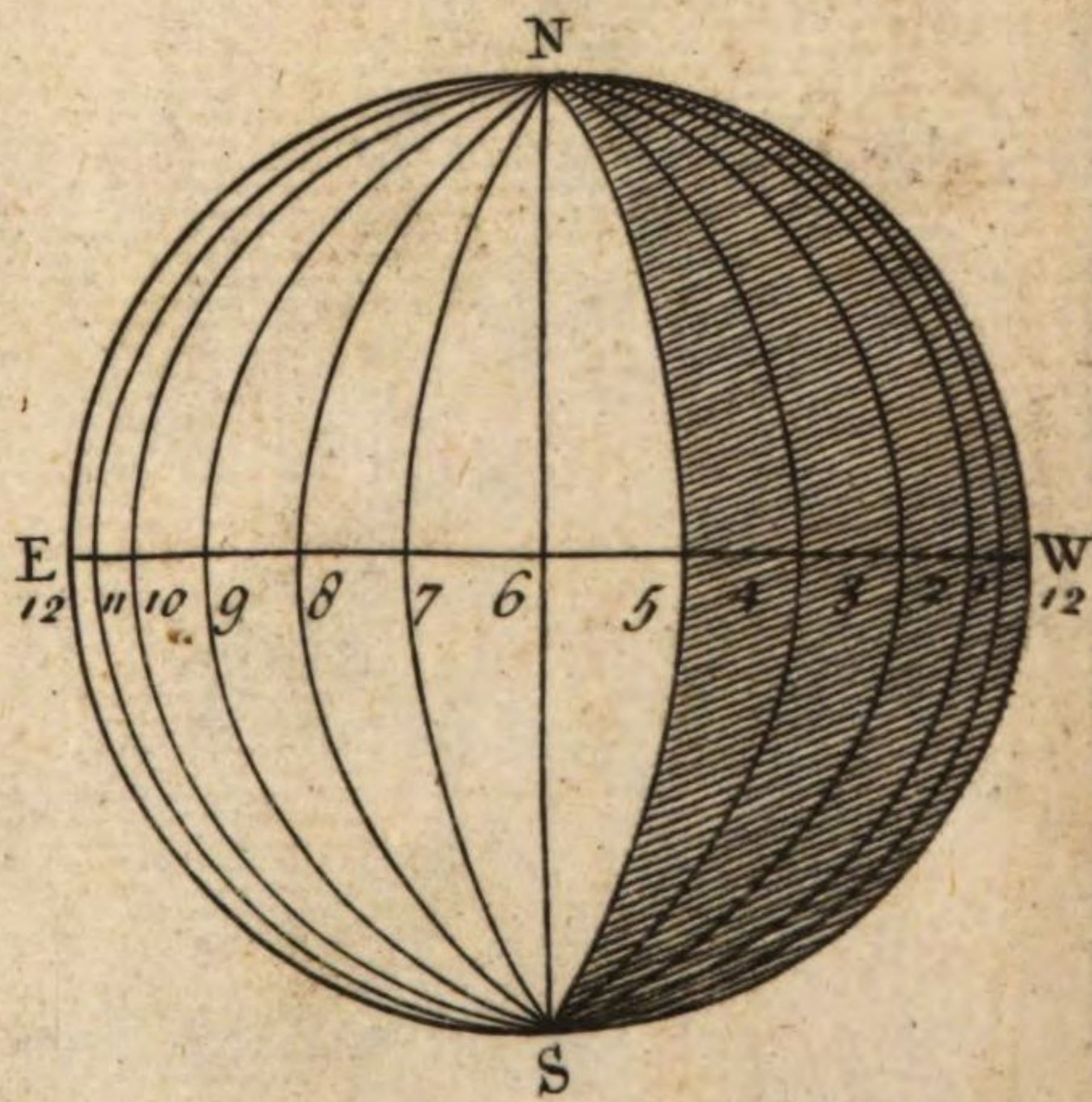


Fig. A. p. 830.

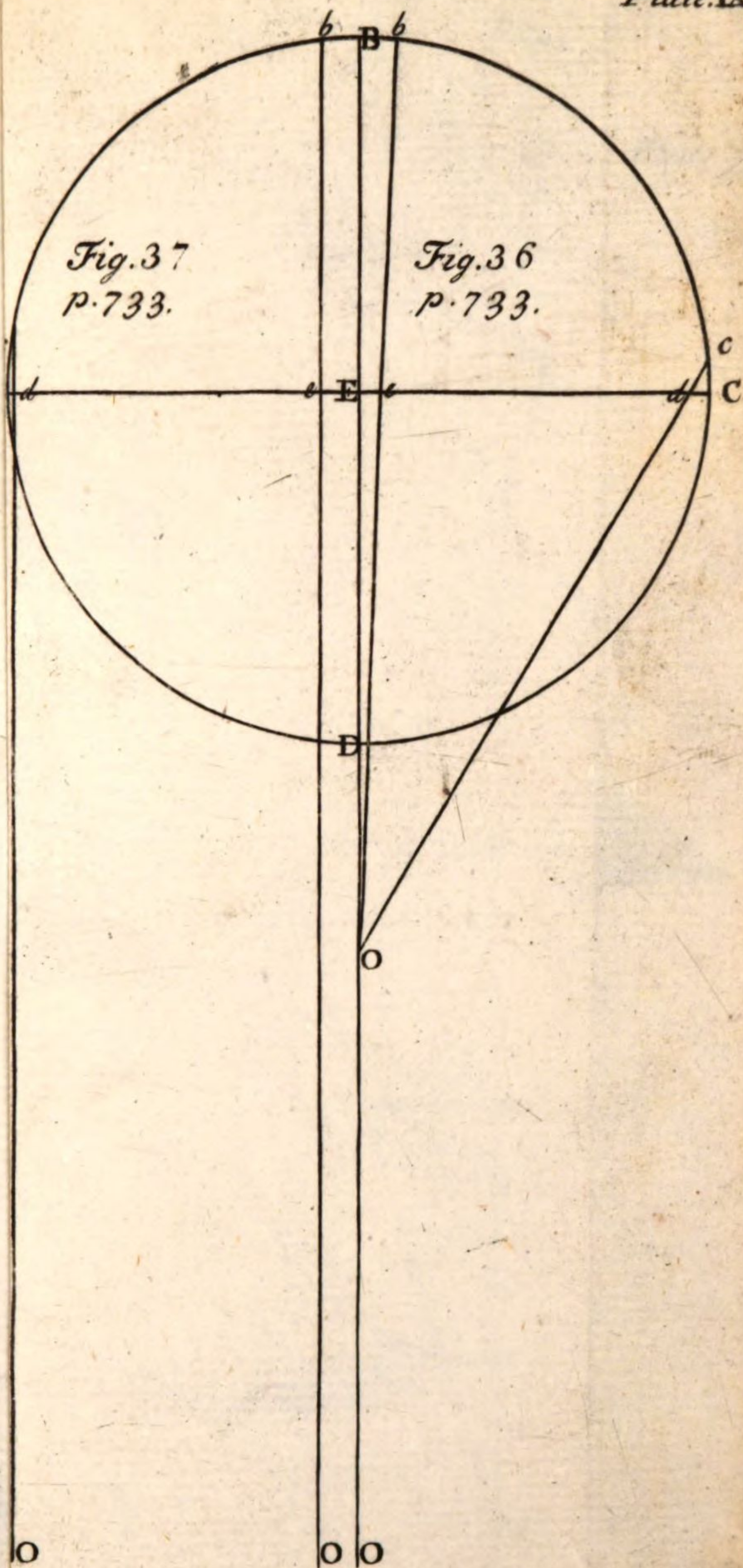


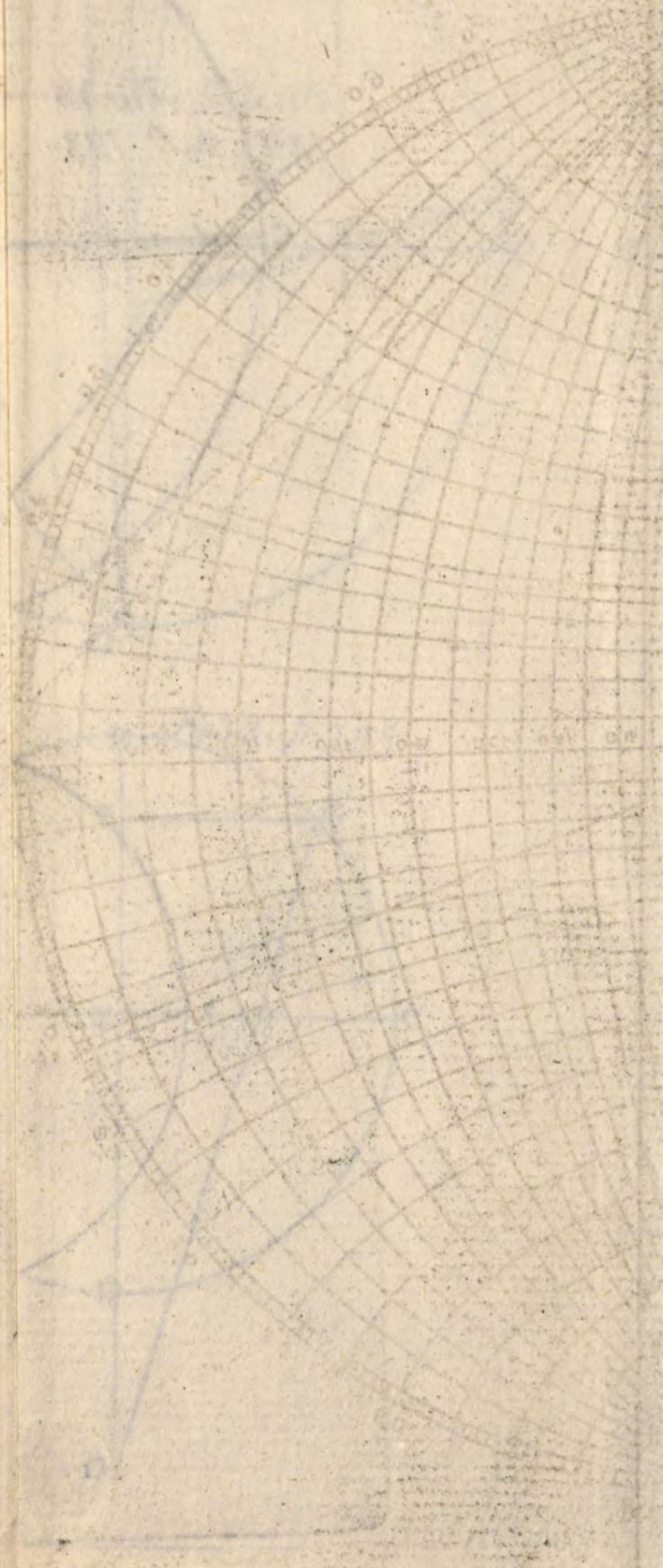


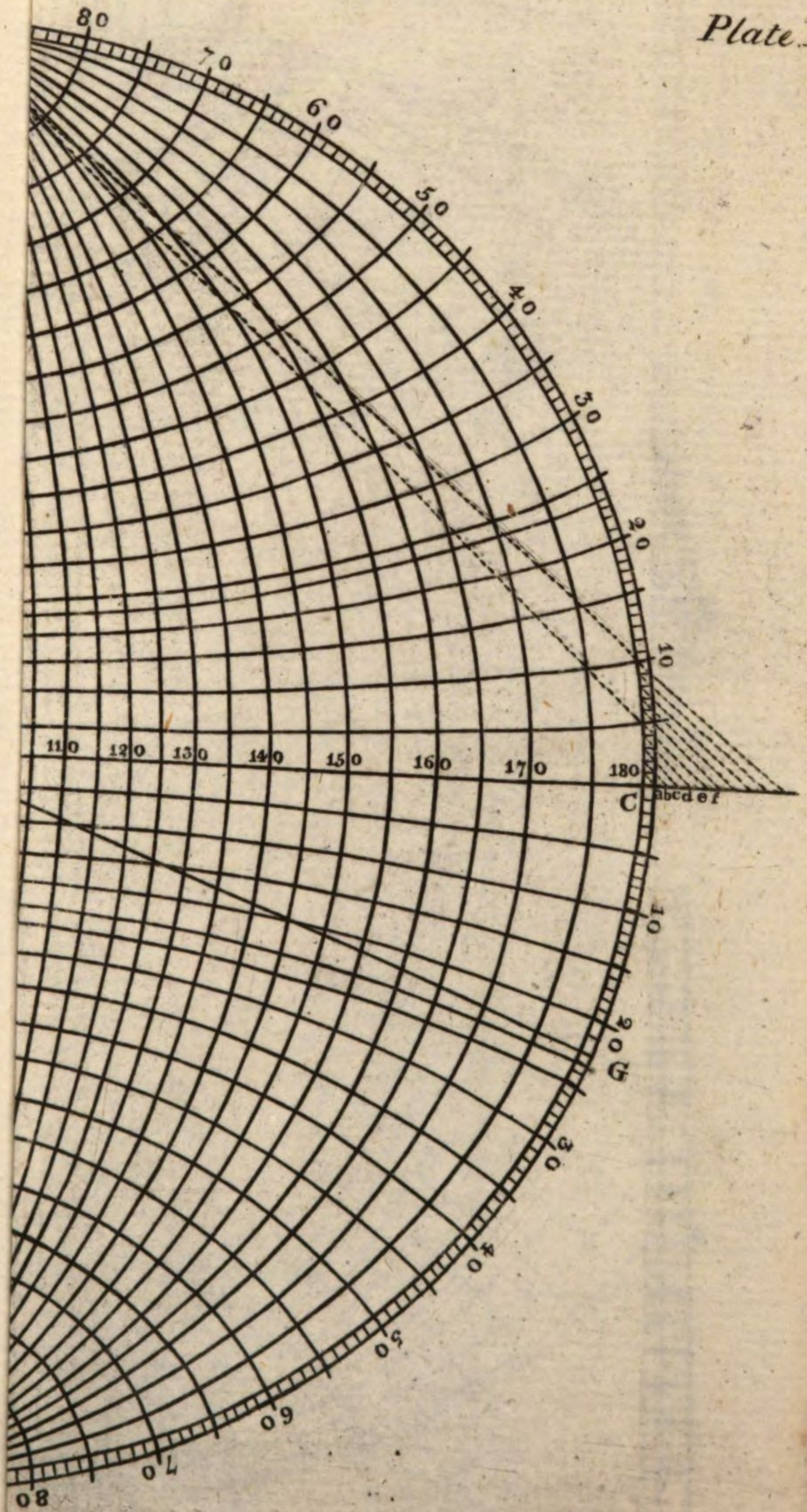
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Top. 30 805 9







Plat. XI.

Fig. B. p. 600.

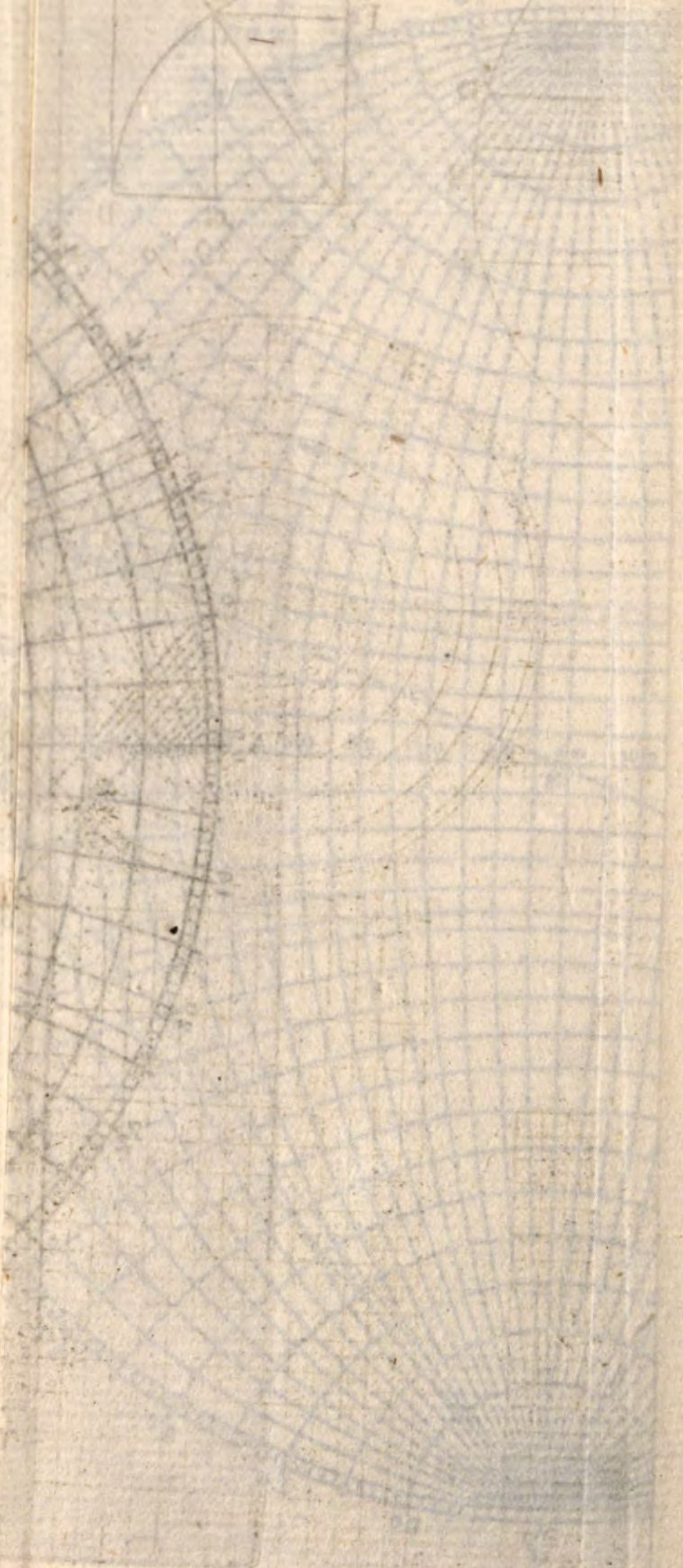


Fig. B. p. 860

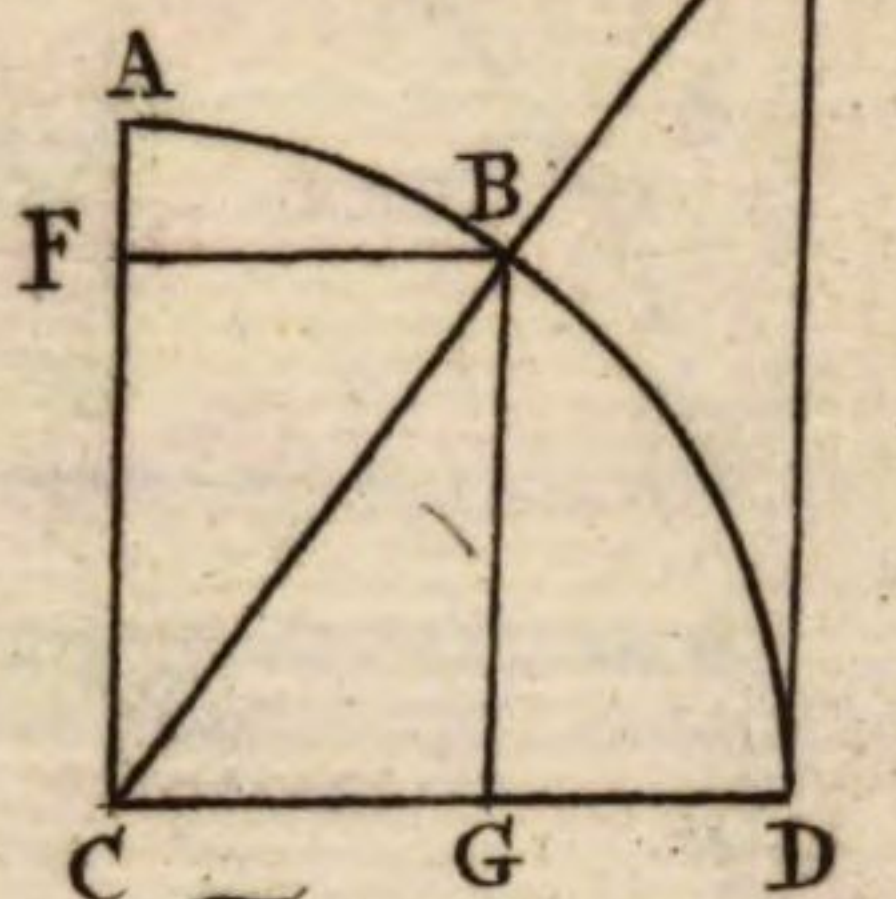


Fig. 39. p. 739

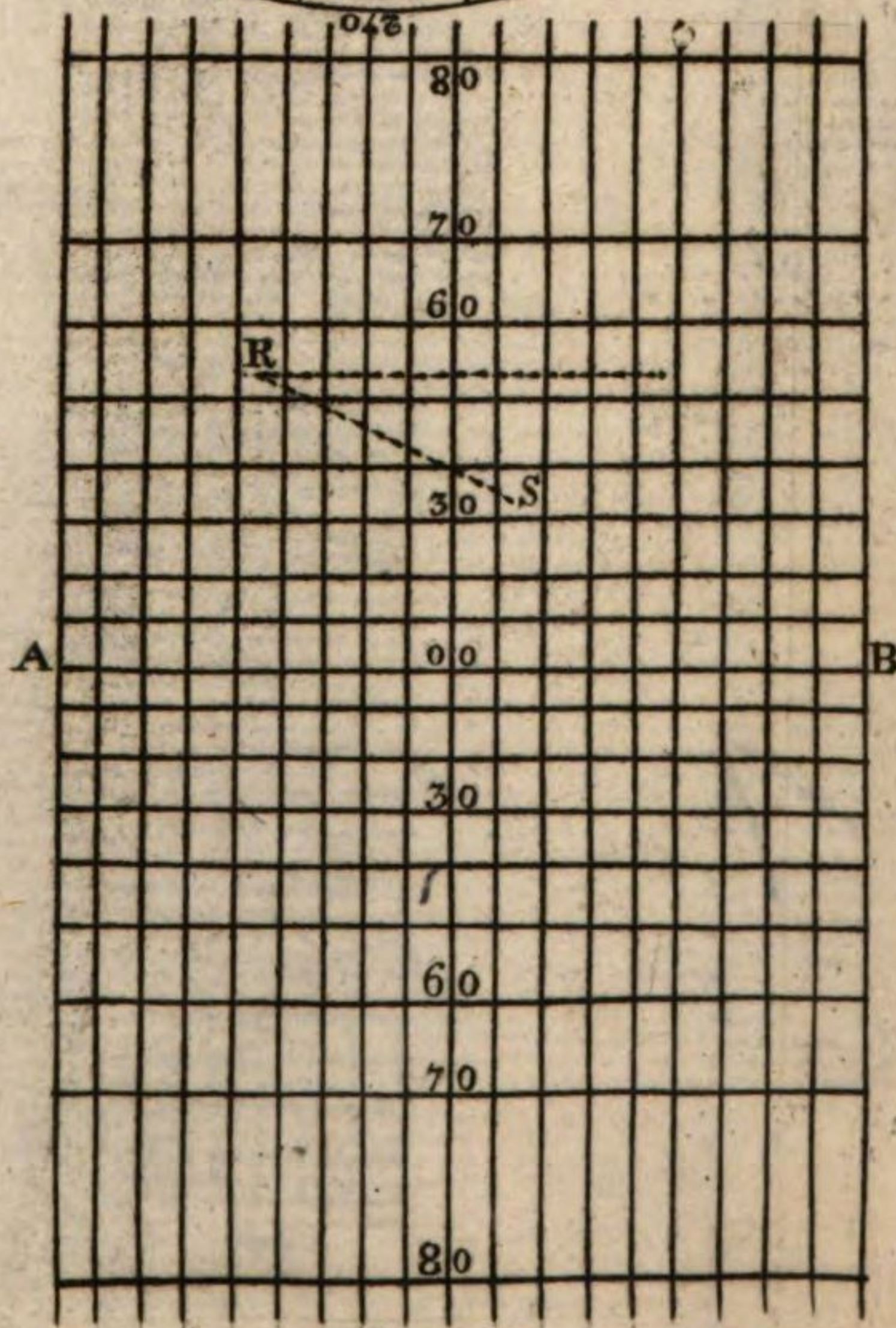
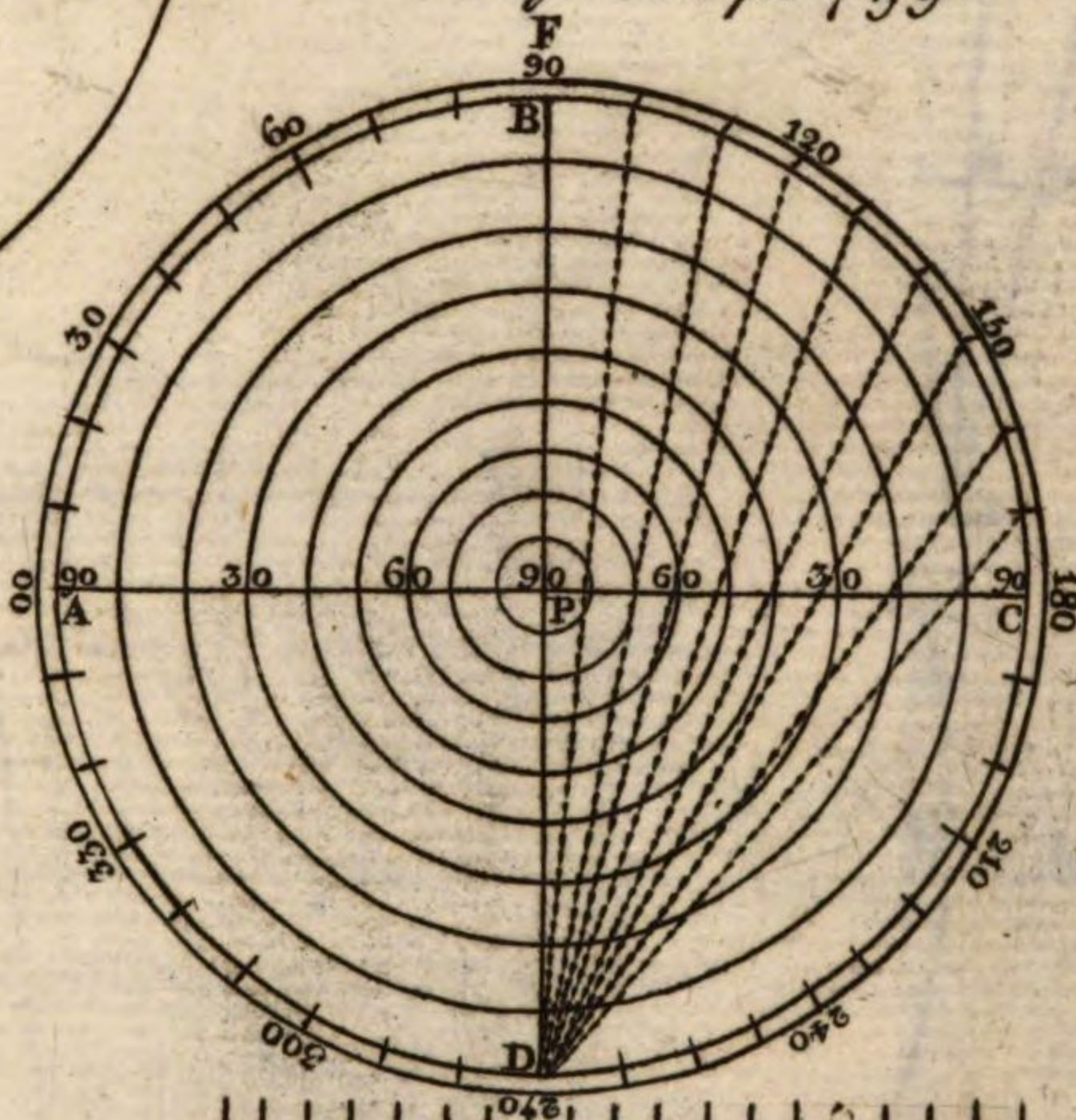
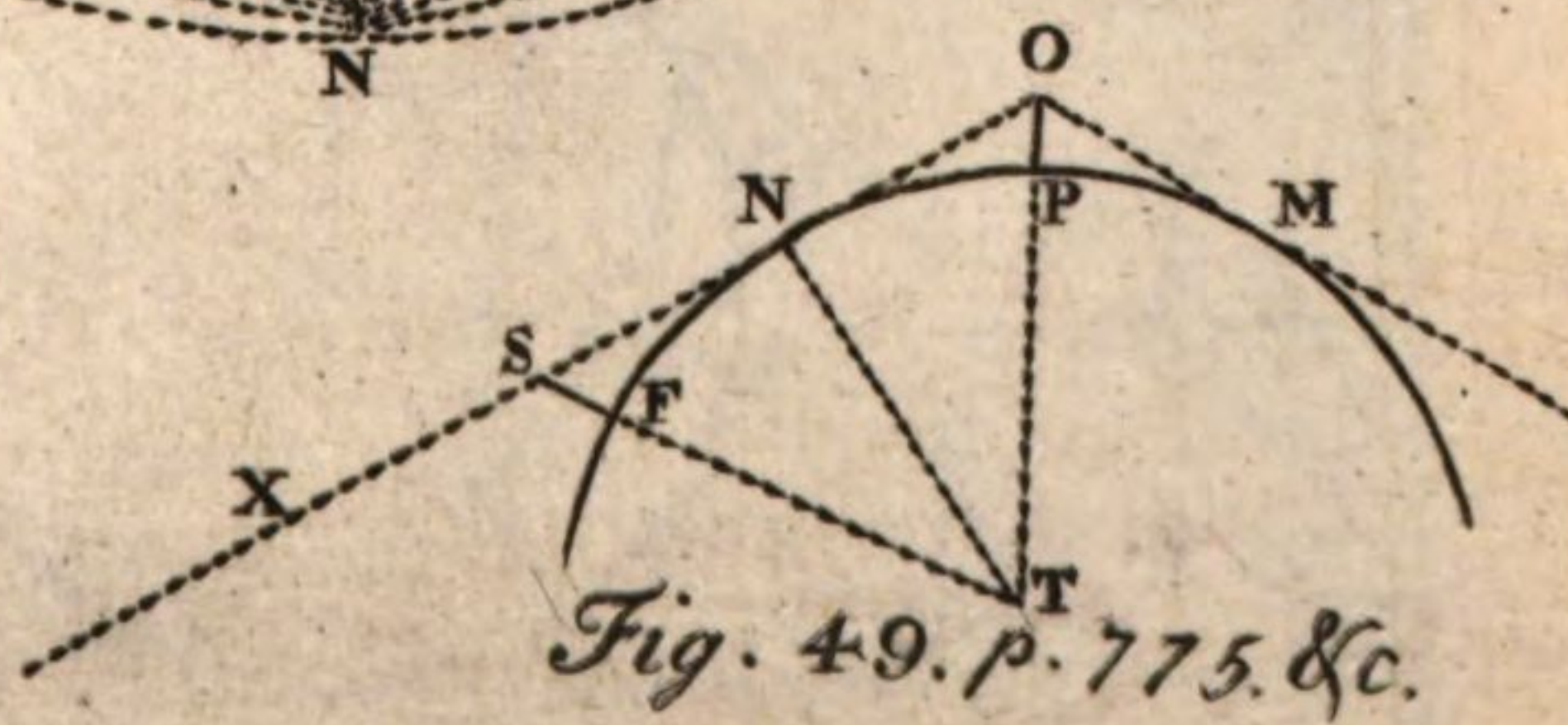
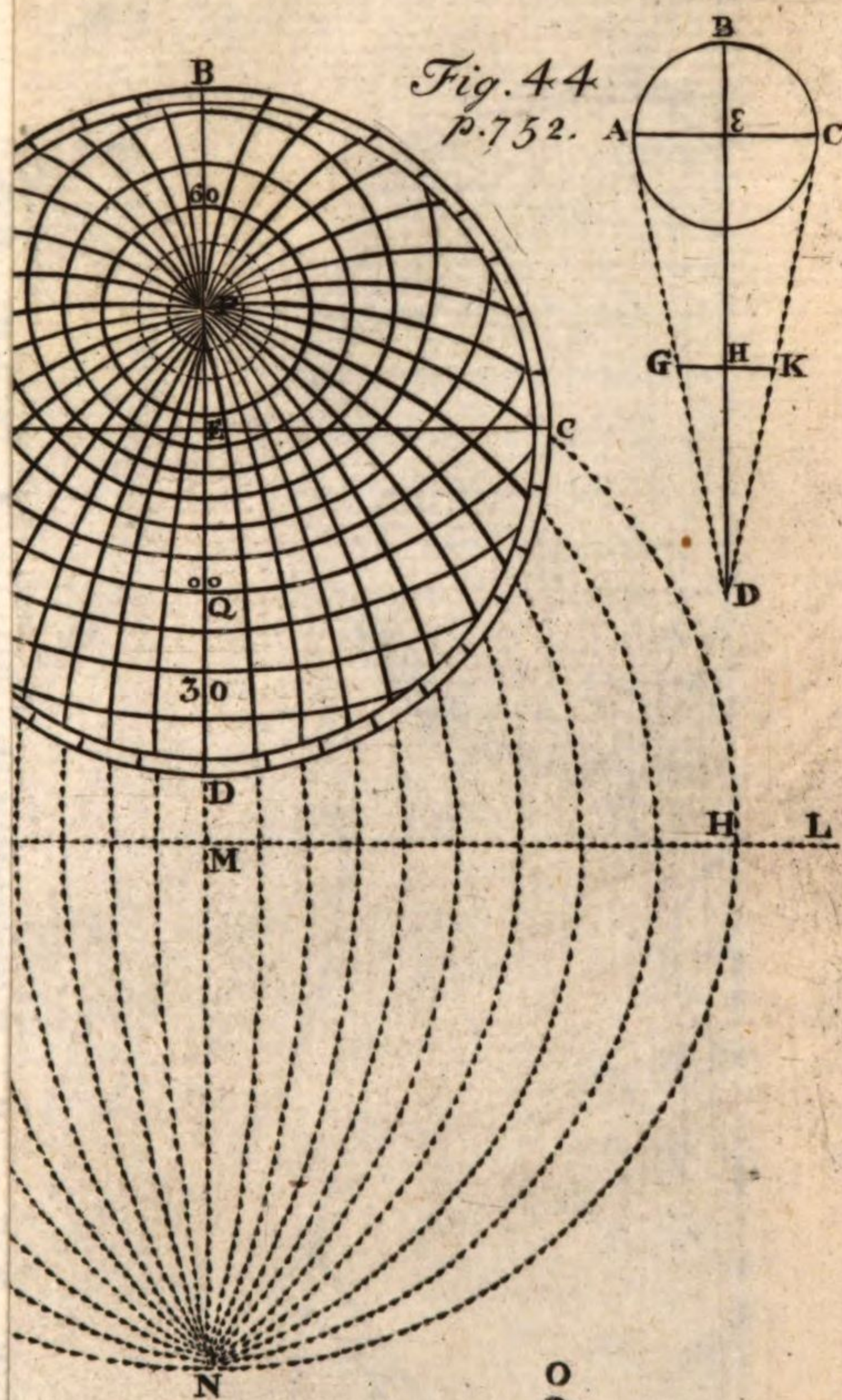


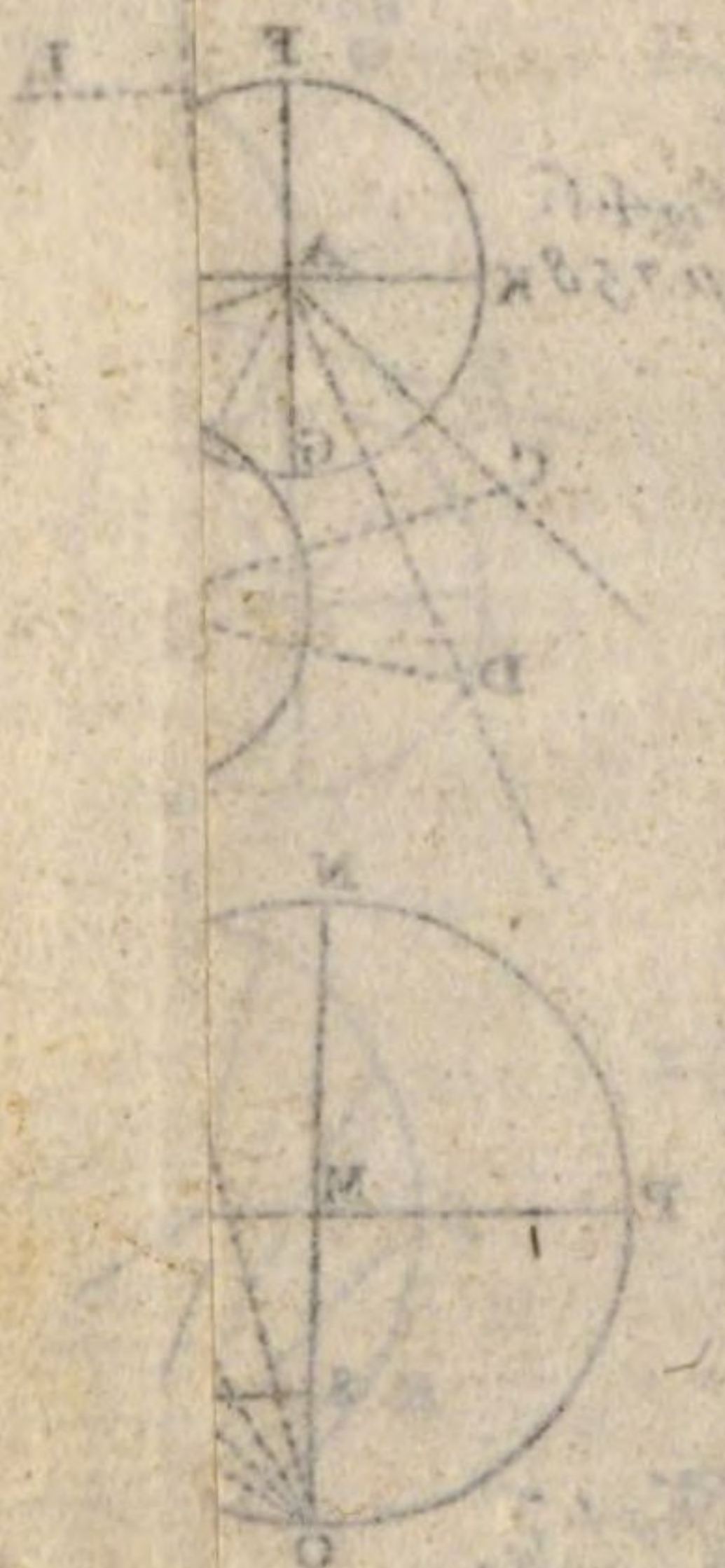
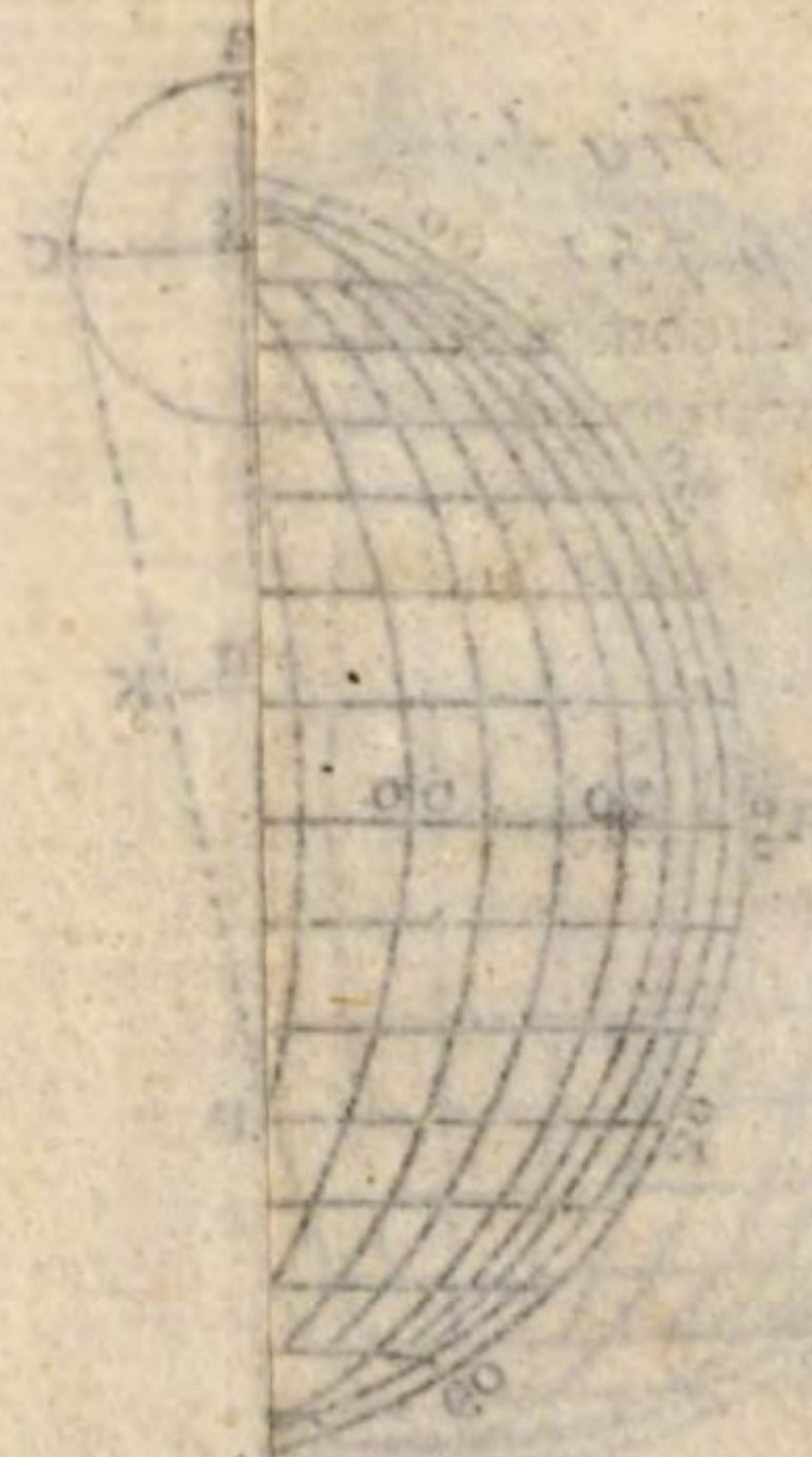
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